DOCUMENT RESUME

ED 105 083 CE 003 313

TITLE	Milling Machine Operator: Instructor's Guide for an Adult Course.
INSTITUTION	New York State Education Dept., Albany. Bureau of Continuing Education Curriculum Development.; New York State Education Dept., Albany. Bureau of Secondary Curriculum Development.
PUB DATE	74
NOTE	161p.
EDRS PRICE	MF-$0.76 HC-$8.24 PLUS POSTAGE
DESCRIPTORS	Course Content; Course Objectives; *Machine Tools; *Metal Working Occupations; Post Secondary Education; Secondary Education; *Shop Curriculum; *Teaching Guides; *Trade and Industrial Education

ABSTRACT

The instructor's guide is for a course expected to help meet the need for trained operators in metalworking. Students successfully completing the course will be qualified for an entry-level job as a milling machine operator. The course is suitable for use in adult education programs of school districts, or in manpower development and training programs, and can be adapted for use in secondary schools. The introduction provides general advice for the instructor followed by a content outline including suggestions for teaching. Most of the document is devoted to job sheets listing performance objectives, operations, equipment, materials, selected references, procedure, and techniques and related information for 37 shop jobs for the following 19 shop projects: parallel clamp, parallels, tap wrench, drill stand, 1-2-3 block, T-nut, bench vise, surface gage, fly tool face cutter, arbor press, precision step block, precision angle plate, 3-inch sine plate, planer gage, micrometer boring head, grinding vise, V-block, grinding fixture for thread tool, and helical milling cutter. Detailed drawings for the shop jobs take up the last 55 pages of the guide. The numbers of hours needed for each shop job are indicated: a total of 293 hours is needed to complete all projects. (SA)

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INSTRUCTOR'S GUIDE FOR AN ADULT COURSE

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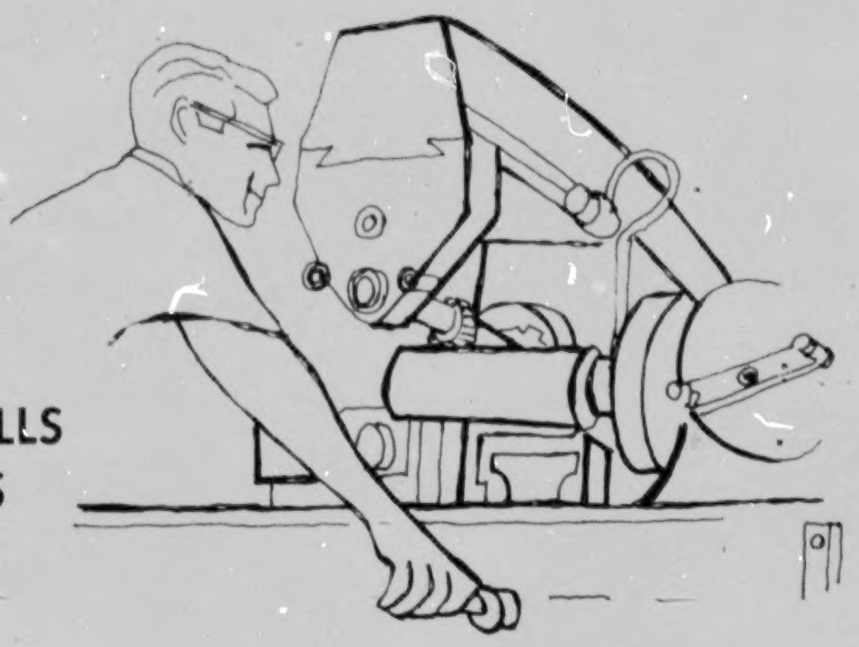

PART OF
SINGLE-TOOL SKILLS
PROGRAM SERIES

CE003313

THE UNIVERSITY OF THE STATE OF NEW YORK/THE STATE EDUCATION DEPARTMENT
BUREAU OF CONTINUING EDUCATION CURRICULUM DEVELOPMENT
BUREAU OF SECONDARY CURRICULUM DEVELOPMENT/ALBANY, NEW YORK 12234

ED105083

Milling Machine Operator

INSTRUCTOR'S GUIDE

Part of
SINGLE-TOOL SKILLS PROGRAM
MACHINE INDUSTRIES OCCUPATIONS

1784

The University of the State of New York
THE STATE EDUCATION DEPARTMENT
Bureau of Continuing Education Curriculum Development
Bureau of Secondary Curriculum Development
Albany, New York 12234
1974

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Foreword

The *Milling Machine Operator* course contained in this book is intended to help fill the need for men trained to operate machine tools. The backgrounds of those who enter the course will cover a broad range of qualifications, but it is likely that many men with little education or experience will be included. Completion of this course alone, obviously will not make anyone a full-fledged machinist.

This course is the third one to be published in a series of instructor's guides for the Single-Tool Skills Program. (*Engine Lathe Operator* was published in 1972 and *Surface Grinder Operator* in 1973.) Although written primarily as an adult course, the secondary level teacher can use the content of this book in a course he might develop for his students. *Milling Machine Operator* was produced as a joint project of the two curriculum bureaus named on the title page.

The Single-Tool Skills Program is one of the programs in a broad plan covering machine industries occupations. The original plan was conceived by Robert S. Hunter, former associate in the Bureau of Trade and Technical Education. A number of teachers were involved in the overall planning for machine industries occupations and also wrote material for the course guides. They are Elek D. Csont, Seneca Vocational High School, Buffalo; Jack Grossman, Alexander Hamilton High School, Brooklyn; Alfred Kagan, Sewanhaka High School, Floral Park; Gilbert Pultz, Jefferson Vocational and Technical Center, Watertown; William G. Stewart, North Senior High School, Binghamton; William F. Tiedemann, Central Technical High School, Syracuse; and Joseph Waldinsperger, College of Continuing Education, Rochester Institute of Technology, Rochester.

Other members of the State Education Department took part in the overall planning and in the further detailed planning which resulted in the production of this publication. They are E. Noah Gould, associate in the Bureau of Continuing Curriculum; G. Earl Hay, supervisor in the Bureau of Secondary Curriculum; Edward Shattuck, former associate in the Bureau of Trade and Technical Education; and Charles A. Stebbins, associate in the last-named bureau.

Messrs. Kagan, Pultz, Stewart, and Tiedemann wrote the *Milling Machine Operator* course contained in this book. Vincent Liuzzi, training administrator, Watervliet Arsenal, Watervliet, helped prepare material for the metric projects and made a number of the drawings. Mr. Gould, who is in general charge of the Single-Tool Skills series, directly supervised the writing and edited the manuscript.

HERBERT BOTHAMLEY, *Chief*
Bureau of Continuing Education
Curriculum Development

GORDON E. VAN HOOFT, *Director*
Division of Curriculum Development

Message to the Instructor

This *Milling Machine Operator* course is expected to help meet the need for trained operators in metalworking. The course is suitable for use in the adult education programs of school districts, in Manpower Development and Training programs, and can be adapted for use in secondary schools.

Anyone who completes this course successfully will be qualified for an entry-level job as operator of a milling machine. Some students may also complete other single-tool courses and qualify to operate more than one machine tool. It is even possible that a student with outstanding ability, by completing the courses for several machine tools, could become a machinist.

The 19 projects in this course (which include 37 shop jobs) are listed on pages 1 and 2. There is no requirement that any student complete all projects, or even all jobs within any project. The instructor may determine which projects and jobs a given student should complete, and whether to have him use conventional or metric dimensions. The instructor may also use other jobs not included in this book.

The teacher for this course would ideally be a person with not only good training and experience in machinist skills, but also several years of teaching experience. The best sources from which to draw teachers are the faculties of schools giving machine tool courses, and the ranks of those employed as machinists and supervisors of machinists.

An administrator or instructor who has any questions or comments about this publication should direct them to either the Bureau of Trade and Technical Education or to one of the bureaus named on the title page.

CARL G. BENENATI, *Chief*
Bureau of Trade and
Technical Education

ROBERT H. BIELEFELD, *Director*
Division of Occupational Education Instruction

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MACHINE INDUSTRIES OCCUPATIONS
SINGLE-TOOL SKILLS PROGRAM
MILLING MACHINE OPERATOR COURSE

LIST OF SHOP PROJECTS

Project No.		Time (hrs.)	Page
I.	Parallel Clamp		
	Job 1A. Parallel Clamp Jaws (inches)	6	18
	Job 1B. Parallel Clamp Jaws (millimeters)	6	20
	Job 2. Straight Clip	1½	22
II.	Parallels		
	Job 1A. Parallels (inches)	6	24
	Job 1B. Parallels (millimeters)	6	27
III.	Tap Wrench		
	Job 1. Tap Wrench Body	2	30
IV.	Drill Stand		
	Job 1. Drill Stand	5	31
V.	1-2-3 Block		
	Job 1. 1-2-3 Block	8	33
VI.	T-Nut		
	Job 1. T-Nut	4	35
VII.	Bench Vise		
	Job 1. Fixed and Movable Jaws	6	37
VIII.	Surface Gage		
	Job 1. Base (Dual dimensions)	6	39
	Job 2. Adjustment Bar (Dual dimensions)	3	41
IX.	Fly-Tool Face Cutter		
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X.	Arbor Press		
	Job 1. Base	7	44
	Job 2. Column	12	46
	Job 3. Cover Plate	2	48
	Job 4. Table	6	49
	Job 5. Gear Shaft	6	51
	Job 6. Rack	7	53
XI.	Precision Step Block		
	Job 1. Precision Step Block	10	55
XII.	Precision Angle Plate		
	Job 1A. Precision Angle Plate (inches)	10	58
	Job 1B. Precision Angle Plate (millimeters)	10	60

Project No.		Time (hrs.)	Page
XIII.	3-Inch Sine Plate		
	Job 1. Plate	12	62
	Job 2. End Stop	4	64
XIV.	Planer Gage		
	Job 1. Base	12	65
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XV.	Micrometer Boring Head		
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	Job 1. Lead Screw Nut	3	78
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XVIII.	Grinding Fixture for Thread Tool		
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XIX.	Helical Milling Cutter		
	Job 1. Helical Milling Cutter	16	93

Total time for shop projects 293 hours

MACHINE INDUSTRIES OCCUPATIONS
SINGLE-TOOL SKILLS PROGRAM
MILLING MACHINE OPERATOR COURSE

LIST OF DRAWINGS FOR SHOP PROJECTS

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15	Bench Vise Assembly	VII	1	100
16	Bench Vise Details		1	101
17	Bench Vise: Fixed and Movable Jaws		1	102
21	Tap Wrench	III	1	103
22	Micrometer Boring Head: Assembly	XV	1-4	104
22.1	Micrometer Boring Head: Plate		2	105
22.2	Micrometer Boring Head: Dovetail Blocks		3	106
23	Micrometer Boring Head: Dial, Shank, and Stop Pin		1	107
24	Micrometer Boring Head: Dovetail Slide		4	108
25	Surface Gage: Assembly	VIII	1,2	109
25.1	Surface Gage: Base (Dual Dimensioning)		1	110
25.2	Surface Gage: Adjustment Bar (Dual Dimensioning)		2	111
26	Surface Gage: Details		1,2	112
27	Arbor Press: Assembly	X	1-6	113
28	Arbor Press: Gear Shaft, Rack Pad, and Rack		5,6	114
29	Arbor Press: Table		4	115
30	Arbor Press: Sleeve, Table Pin, and Cover Plate		3	116
31	Arbor Press: Handle and End		-	117
32	Arbor Press: Column		2	118
33	Arbor Press: Base		1	119
36	Grinding Vise Assembly	XVI	1-4	120
37	Grinding Vise: Lead Screw Nut		1	121
38	Grinding Vise: Lead Screw and End Nut		3	122
39	Grinding Vise: Base		4	123
40	Grinding Vise: Sliding Jaw		2	124
42	Drill Stand	IV	1	125
44	Precision Step Block	XI	1	126
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46A	Precision Angle Plate (Inches)	XII	1A	128
46B	Precision Angle Plate (Millimeters)		1B	129
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Dwg. No.	Title of Drawing	Project	Milling Machine Jobs Covered	Page
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55	Grinding Fixture for Thread Tool: Nut and Bolt		-	136
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57A	Parallel Clamp: Loose Jaw (Inches)		1A	138
57B	Parallel Clamp: Loose Jaw (Millimeters)		1B	139
58A	Parallel Clamp: Threaded Jaw (Inches)		1A	140
58B	Parallel Clamp: Threaded Jaw (Millimeters)		1B	141
59	Parallel Clamp: Straight Clip		2	142
60	Parallel Clamp: Clamping Screw		-	143
61	Parallel Clamp: Adjusting Screw		-	144
62	T-Nut	VI	1	145
63	3-Inch Sine Plate	XIII	1	146
64	3-Inch Sine Plate: End Stop		2	147
65	Planer Gage Assembly	XIV	1,2	148
66	Planer Gage: Base		1	149
67	Planer Gage: Slide		2	150
68	Planer Gage: Extension		-	151
69	Planer Gage: Clamping Nut		-	152
70	Planer Gage: T-Bolt			153
71	Helical Milling Cutter	XIX	1	154

Introduction

As shown in the contents, this *Milling Machine Operator* course consists of this Introduction, General Job Content (which explains what the operator's job includes), Job Sheets for projects, and the drawings for the projects. The course covers the operation of the milling machine only.

Objectives of the Course

The job for which the trainee would be qualified upon completion of this course is referred to in the Dictionary of Occupational Titles (under the code number 605.380) as milling machine operator; milling machine setup man; milling machine setup operator, tool; and precision milling machine operator. It might also fit into the categories of milling machine operator, production (code number 605.885); or milling machine setup operator (code number 605.782).

The general objective of the course is to train men, in a comparatively short time, to be placed as milling machine operators. Another important purpose is to help those with very little background. The course is not intended to give a broad training in metalworking, but only the skill to operate one kind of metalworking machine. By keeping the objective narrow, the training time is kept to a minimum, and the trainees are made available for work without a long delay.

Units of Measurement

Generally speaking, conventional units of measurement (inches for linear dimensions, and degrees for angles) are used in this course. However, an attempt has been made to introduce the students to metric measurement by using millimeters for dimensions in several projects, in addition to the conventional units.

The United States is the only big country in the world which is not either using metric measurements or in a program for changing to metrics. Legislation is now pending in Congress which is likely to start us on a 10-year changeover period which would result in making metric units the predominant means of measurement. The much greater convenience of metric units and our increasing trade with countries on the metric system are the main forces pushing us toward metrication.

In American industry some companies are already using metric measurements to a large extent in their products. Examples of such companies are the Beloit Tool Corporation of South Beloit, Illinois, and the Caterpillar Tractor Company of Peoria, Illinois. American metalworking companies using metric units are apparently continuing to use conventional thread systems. This is because, according to some authorities, the conventional threads have some significant advantages over metric threads. References listed in the bibliography contain further information on metrics.

Metric Units in this Course

In this course the workpieces for three shop jobs have been designed in both conventional and metric units. Job Sheets and drawings using both inches and millimeters are included so an instructor can have a student make these pieces in either conventional or metric dimensions or both. Two shop jobs in another project have had dual dimensions applied to them. The projects and jobs which have been changed are:

Project	Job		
I	1	Parallel Clamp Jaws	Designed in conventional and metric units
II	1	Parallels	Designed in conventional and metric units
XII	1	Precision Angle Plate	Designed in conventional and metric units
VIII		Surface Gage	
	1	Base	Dual dimensions applied to drawings
	2	Adjustment Bar	Dual dimensions applied to drawings

In Projects I, II, and XII, Job 1A is in conventional units and Job 1B is in metric units. In Project VIII the Job Sheets use conventional units in describing each step of the work, and only the drawings show both kinds of units. The metric figures in these jobs are limited to linear dimensions, including hole diameters generally. However, tapped holes in all cases are in inches. For all these jobs the only additional instruments suggested are a 15 cm. metric scale, a 0-25 mm. micrometer, and a metric dial indicator.

Drawings and Job Sheets

The drawings in this course are part of a serially numbered set beginning with No. 1, which appears in the *Engine Lathe Operator* course. The numbers continue through the drawings of this course and will be continued further in any other courses in the Single-Tool Skills Program which might be published later. Drawings in this course which are also in one of the other courses are reproduced here with the same drawing numbers. Some drawings appear in this book which are not needed for the shop projects of this course. They are included here for the convenience of keeping together all the drawings of an assembly. Those in this publication run from 8 through 71 of the series.

In the drawings all dimensions are in inches unless otherwise indicated. A number of drawings contain tables giving several different sets of dimensions for the workpieces pictured. These tables permit the instructor to select the set of dimensions which he finds best for each student or for the conditions under which his class operates.

Each job sheet has the words *Unit No.* in the upper left corner, but no number is given. The instructor may wish to write a number in this space to fit in with his own method of organizing his classroom and shop work.

Assignment of Work to Students

As a shop project is assigned to a student, we recommend that the instructor give him copies of the applicable Job Sheets and drawings. The binding of this book permits easy removal of pages for making copies. When copies are made,the pages themselves must be kept clean and should not be used by anyone working on a machine. After any copies are made the pages should be replaced in the book and the book should be kept in a looseleaf cover.

Each drawing has four blocks for information at the bottom and two of them are blank. We suggest that the instructor have the student write the numbers of the project and job for which he is using the drawing in one of these blank spaces.

Many of the workpieces on which milling is to be done in this course are those produced in other courses in the Single-Tool Skills series. If a given workpiece is not available as the output of another course in his shop, it is the instructor's responsibility to obtain the workpiece. In some cases he may need to make it himself.

Administration of the Course

We believe that enough general information about the job and more than enough shop projects are included for the trainee to reach the general objective of the course. All essential milling machine skills are used in the shop projects a number of times.

The schools may use everything in the course, they may select only some of the material, they may make changes in it, and they may use other material not contained here. They may also determine the length of the class periods, their frequency, and the total amount of time to be spent in training. For those that need a guide: A typical adult night class runs 2 $\frac{1}{2}$ to 3 hours, either once or twice a week, for 30 weeks.

The prerequisites for admission to an adult course should be broad enough so none will be barred who could be made employable. The operating authorities for each program, school, and school district have the responsibility for determining the prerequisites for such a course, and can adapt them to any special local conditions.

The *minimum* prerequisites we suggest for a trainee (and they are not mandatory) are that he have enough ability to understand and follow the course instructions (both written and oral) so he can produce the simplest workpiece included in the course. Such a trainee will, perhaps, be able to qualify only as a production machine operator, where all the machine setups are made for him. Another trainee with more background will possibly qualify for jobs requiring more skill, such as milling machine setup man.

The Job Sheets show three references which are especially recommended for the machine work. The bibliography gives the complete citations for these two books and also contains additional references.

Abbreviations Used in Text and Drawings

ALUM.	aluminum
ASSY.	assembly
CHAM.	chamfer
CBORE.	counterbore
CM.	centimeter(s)
CRS	cold rolled steel
CSK.	countersink
DIA.	diameter
DP.	deep
DP	diametral pitch
DR.	drill
DR or DR. ROD	drill rod
EQ. SP.	equally spaced
FAO	finish all over
HD	head
HDL.	handle
HGT.	height
HEX.	hexagonal
H.S.	high-speed
HT.	height
LG.	long
LGTH.	length
MATL.	material
MED.	medium
MM.	millimeters
PT.	part
R or RAD.	radius
REQD.	required
R.H.	right-hand
SCR.	screw
SOC.	socket
SPEC.	specifications
SPHER.	spherical
STL.	steel
SQ.	square
TYP.	typical
W.	width

General Job Content

I.	Types of Machine	Discuss the various types of milling machines. Two major types are: the knee-column type and the bed type. Point out that the knee-column type is most common in the toolroom and may have either a horizontal or vertical spindle.
	A. Bed types	Describe the various bed type millers including horizontal spindle, planer, and special application machines.
	B. Tracer controlled	Mention that tracer controlled milling follows the same basic milling functions as manually controlled machines. The milling machine is automatically controlled by the reaction of the tracing stylus on the master template.
II.	Machine parts	Give the names of the parts of the milling machine, some of which are: base, knee, spindle, and table.
III.	Machine Accessories A. Toolholding	Provide information about the types of toolholders available, including: arbors, collets, and rack milling attachment.
	B. Work holding	Identify the types of work holding devices commonly used, such as: swivel vise, index head, and milling fixture.
IV.	Cutting Tools	Explain that milling cutters are classified by their use and by their shape or type of cutting teeth. Some of the classes are: gear tooth, concave, stagger tooth, inserted tooth, and ball-end mill.
	A. Keyseat cutters	Point out that keyseat cutters fall into two general categories, and that all sizes are designated by either the American standard number or the manufacturer's number.
	B. Gear cutters	Explain that there are either 8 or 16 cutters in a set for gear tooth cutting, and the selection of the proper set depends upon the number of teeth to be cut.

CONTENT OUTLINE		TEACHING POINTS AND TECHNIQUES
		Identify some parts of the milling cutter, such as: 1. tooth 2. shank 3. rake 4. clearance 5. cutting edge 6. helix angle
V.	Measurement and Inspection	Explain the various types of measuring tools. These could include: 1. micrometer (including metric micrometer) 2. indicator 3. air gage 4. go and no-go gage 5. metric scale
VI.	Blueprint Reading	Cover all necessary blueprint reading, including: 1. theory of orthographic projection 2. language of lines 3. sectional views 4. tolerances 5. dual dimensioning (as in Project VIII)
VII.	Speeds and Feeds	Call attention to the conditions which determine choice of speed and feed. Some of these conditions are: 1. composition and hardness of work material 2. depth of cut 3. efficiency of cutting fluid 4. condition of machine 5. quality of finish required Explain how to use cutting speed charts. Introduce the formula for finding the approximate r.p.m. for the cutter: $\text{r.p.m.} = \frac{4\ (CS)}{D}$ where CS = cutting speed in feet per minute and D = diameter in inches
VIII.	Trade Mathematics	Cover all necessary trade mathematics, such as: 1. basic arithmetic 2. constants 3. use of formulas
IX.	Coolants	Develop an understanding of coolants, including the following types: 1. water base type 2. oil type 3. chemically active sulphurized fatty type 4. sulphurized mineral oils

CONTENT OUTLINE		TEACHING POINTS AND TECHNIQUES
X.	Care and Maintenance	Provide information about the care and maintenance of the various types of milling machines, which might involve such things as: 1. Wiping a tapered spindle hole before inserting a tool 2. Making sure the machine is properly oiled 3. Using the proper operations and repair manual for maintenance on the milling machine
XI.	Safety	Introduce the following safe working practices for operating milling machines: 1. Wear close-fitting clothing. 2. Wear safety glasses. 3. Make sure all guards are in place. 4. Keep hands away from moving parts. 5. Know how to operate the controls. Discuss ways of avoiding dangers when operating the milling machine, such as the following: 1. Make sure that the work is held securely in the holding fixture. 2. Mount the milling cutter properly. 3. Never attempt to clean the machine while it is in motion. 4. Do not stand in the line of cutter rotation. 5. Be sure to use the proper rate of feed for the cutter type. 6. Do not move chips by hand — use a brush or other instrument. 7. Use a shop cloth when handling milling cutters.
XII.	Trade Terms	Explain all terms which are pertinent to this machine, for example: *climb milling*, in which the work feeds in the same direction as the cutter.
XIII.	Operations	
	A. Angular milling	Describe to the class the various types of angular milling cutters, some of which are: 1. single angle 2. double angle 3. standard angle 4. special Point out that some uses of angle cutters are for the milling of dovetails, flutes, and V-notches.

CONTENT OUTLINE	TEACHING POINTS AND TECHNIQUES
B. Plain milling	Discuss specific kinds of plain milling cutters, such as: 1. light duty plain milling cutter 2. heavy duty plain milling cutter 3. helical milling cutter Describe the differences between side milling cutters and plain milling cutters, which include: 1. no side teeth 2. staggered teeth 3. interlocking teeth
C. Face milling	Point out that face milling cutters are wide-faced cutters designed to machine the entire surface of a part in one pass. Explain that face milling cutters are mounted directly on the spindle nose and are usually of inserted tooth design. Also that face milling may also be done by using other types of cutters, such as fly cutters and shell end mills.
D. T-slotting	Describe the special features of T-slot cutters which cut on the circumference on both sides. Remind the students that a central groove in a part must be cut prior to machining the wider part with the staggered tooth T-slot cutter.
E. Straddle milling	Show how straddle milling can reduce milling time by cutting both sides or ends of a piece at the same time. Straddle milling cutters include: 1. side milling cutters 2. half side cutters 3. staggered tooth cutters of various widths Point out that different distances between cuts may be obtained by use of collars and shims of different widths.
F. Form milling	Describe to the class both types of form cutters: profile-ground and form-relieved cutters. The profile-ground cutters are the fixed or inserted tooth type and the form-relieved cutters are the solid type.
G. Drilling	Demonstrate how to set up adapters and drill chucks in a milling machine spindle for drilling.

CONTENT OUTLINE	TEACHING POINTS AND TECHNIQUES
	Explain how drills are classified by number and letter and by millimeter, and fractional inch sizes.
	Distribute material explaining causes of drill failure, some of which are: 1. excessive r.p.m. 2. excessive feed 3. improper sharpening of the drill bit
H. Slotting	Identify types of cutters used in cutting slots, for example: 1. metal slitting cutters 2. staggered tooth cutters 3. side milling cutters
	Explain how a choice would be made between climb milling and conventional milling for a given job. Some advantages of climb milling are: 1. better finish 2. less tendency to chatter 3. lower power requirements
	Some advantages of conventional milling are: 1. Backlash is eliminated. 2. Life of the cutter is not affected by sandy or scaly surfaces.
J. Boring	Explain that boring is done to enlarge or true up a hole.
	Describe the various boring operations possible with the following tools: 1. a bar with an adjustable tool bit 2. an adjustable boring-facing head 3. an adjustable multipurpose boring bar to cut one or more diameters
	Emphasize the importance of using a boring bar of minimum length and maximum diameter to overcome spring.
	Point out that boring can be done with either a horizontal or vertical spindle.
K. Keyseat cutting	Identify the methods used to machine a keyseat in a shaft. Also mention the various ways of mounting the shafts for this cutting operation.
	State that the keyseat must be parallel to the axis and centrally located. Also that keyseats are often machined with an end mill.

CONTENT OUTLINE	TEACHING POINTS AND TECHNIQUES
L. End milling	Explain that the end mill cuts on both the end face and the periphery. Styles available include: 1. two-lipped 2. multiple lipped 3. straight and helical 4. single and double end 5. straight and taper shank 6. radius or ball-end
M. Setting up	Point out the areas to be checked when setting up precision equipment on the milling machine. For example: 1. Solid jaw of the vise must be indicated for precision work. 2. Tapered shanks should be wiped clean and checked for nicks and burrs before being put into spindle. 3. All collars and cutters should be wiped clean before being put on the arbor. 4. The dividing head and tailstock must be indicated for proper alinement. 5. To avoid an accident the slotting head should be checked for length and position of stroke before bringing work up close to it. 6. The vertical head should be accurately positioned by sweeping the table with an indicator. Expand further on the use of the precision-table locating devices, which may be mechanical, optical, or electrical. Explain how the dividing head is used to accomplish operations such as: 1. angular milling 2. division machining 3. helical milling
N. Gear cutting	Point out that gear cutting requires the use of a dividing head (index head) to obtain the required number of equally spaced teeth. Mention that a set of at least 8 cutters is required to cut a gear of a particular pitch and size. This also includes a rack.
O. Helical milling	Explain how the index head is geared to the lead screw on a universal milling machine table to cut a helical groove. This arrangement rotates the workpiece while the table moves longitudinally.

CONTENT OUTLINE	TEACHING POINTS AND TECHNIQUES
	Describe the problems in alining a fluting cutter when setting up for helical milling. Mention the types of cutters used for helical milling.
P. Cam milling	Describe how a uniform rise cam may be generated in a blank by the combined uniform rotations of the cam blank (held in the spindle of a universal dividing head) and the uniform feed of the machine table.

Job Sheets for Shop Projects

Now Plug into the Projects!

(Drawing is by courtesy of the American Telephone and Telegraph Company.)

Unit No. *Operator's Job Title:* Milling Machine Operator

Project I *Project Name:* Parallel Clamp

Job No. 1A *Job Name:* Parallel Clamp Jaws (inches) *D.O.T. No.* 605.380

Drawing Nos. 56, 57A, 58A *Time:* 6 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawings in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Plain milling
2. Form milling
3. Setting up
4. Angular milling

Equipment:
Horizontal milling machine
Milling machine vise
Combination square
Surface gage
$\frac{1}{2}$" concave cutter
Side milling cutter

Materials:
2 pieces CRS SAE 1020,
$\frac{1}{2}$" x $\frac{1}{2}$" x $3\frac{1}{2}$"

*Selected references:**
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

NOTE 1:* The job described below (No. 1A) provides for producing workpieces measured conventionally (that is, in inches). Another sheet describes Job 1B which provides for producing essentially the same pieces (parallel clamp jaws) in metric dimensions (that is, millimeters). In both jobs angles are measured in degrees and screw threads and hole diameters are also in conventional measurements.

NOTE 2: The operations shown on this sheet will produce a piece with the dimensions given in Ref. No. 3 of the tables shown on the drawings. The instructor may, however, choose to make a piece to the dimensions of any other Ref. in the tables.

NOTE 3: A drawing is included for parallel clamp screws. These screws can be made on either the engine lathe or the turret lathe.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select stock and remove all burrs.	
2. Set up vise on milling machine with vise jaws at right angles to the T-slots.	2. Be sure to clean machine table and bottom of vise.
3. Set up a side milling cutter.	3. Be sure all arbor collars and the cutter are clean.
4. Clamp workpiece in the vise and mill ends of pieces clean and to size.	4. Work on each piece separately.

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*Full reference citations are given in the bibliography.

PROCEDURE	TECHNIQUES AND RELATED INFO.
Swivel the vise so its jaws are parallel to T-slots of machine table.	
5. Set up piece with angular layout line parallel to the vise jaws; tighten vise. Swivel the vise so its jaws are parallel to T-slots of machine table.	5. Use a surface gage or follow local shop procedure.
6. Mill to layout line.	
7. Remove the milling cutter and mount a $\frac{1}{2}$" concave cutter.	7. Mount cutter so the cutting forces are against the solid jaw.
8. Swivel the vise so jaws are at right angles to the T-slots.	
9. Clamp both workpieces in the vise in an upright position.	9. Use a combination square to aline.
10. Mill the $\frac{1}{4}$" radius.	10. Do not climb mill. Keep the workpiece as deep in the vise as possible.
11. Deburr.	
12. Submit for inspection and grade.	12. Clean all tools and machine. Return all tools to the proper places.

Unit No. *Operator's Job Title:* Milling Machine Operator

Project I *Project Name:* Parallel Clamp

Job No. 1B *Job Name:* Parallel Clamp Jaws (millimeters) *D.O.T. No.* 605.380

Drawing Nos. 56, 57B, 58B *Time:* 6 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawings in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Plain milling
2. Form milling
3. Setting up
4. Angular milling

Equipment:
Horizontal milling machine
Milling machine vise
Combination square
Metric micrometer, 0-25 mm.
15 cm. metric scale
Surface gage
$\frac{1}{2}$" concave cutter
Side milling cutter

Materials:
2 pieces CRS SAE 1020,
13 mm. x 13 mm. x 89 mm.
($\frac{1}{2}$" x $\frac{1}{2}$" x $3\frac{1}{2}$")

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

NOTE 1: The job described below (No. 1B) will produce two pieces essentially the same as those produced by Job 1A. In Job 1B, however, the pieces have been designed in metric dimensions, with some exceptions. In both jobs angles are measured in degrees and screw threads and hole diameters are also in conventional measurements.

NOTE 2: The operations shown on this sheet will produce a piece with the dimensions given in Ref. No. 3 of the tables shown on the drawings. The instructor may, however, choose to make a piece to the dimensions of any other-Ref. in the tables.

NOTE 3: In the Materials section above the dimensions of the pieces needed are shown in mm. Since at this time such materials are more easily available in conventional dimensions, inch dimensions are also given.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select stock and remove all burrs.	1. Lay out for angle cut.
2. Set up vise on milling machine with vise jaws at right angles to the T-slots.	2. Be sure to clean machine table and bottom of vise.
3. Set up a side milling cutter.	3. Be sure all arbor collars and the cutter are clean.

PROCEDURE	TECHNIQUES AND RELATED INFO.
4. Clamp workpiece in the vise and mill ends of pieces clean and to size. Swivel the vise so its jaws are parallel to T-slots of the machine table.	4. Work on each piece separately. Use metric scale.
5. Set up piece with angular layout line parallel to the vise jaws; tighten vise. Swivel the vise so its jaws are parallel to T-slots of the machine table.	5. Use a surface gage or follow local shop procedure.
6. Mill to layout line.	
7. Remove the milling cutter and mount a $\frac{1}{2}$" concave cutter.	7. Mount cutter so the cutting forces are against the solid jaw.
8. Swivel vise so jaws are at right angles to the T-slots.	
9. Clamp both workpieces in the vise in an upright position.	9. Use a combination square to aline.
10. Mill the 6.4 mm. radius, using the $\frac{1}{2}$" concave cutter.	10. Do not climb mill. Keep the workpiece as deep in the vise as possible.
11. Remove the workpiece and take off all burrs and sharp edges.	11. Clean all tools and machine. Return all tools to proper places.
12. Lay out hole locations for later drilling operations.	12. Layout is to be done at layout bench or else use local shop procedure. Use metric scale.
13. Submit for inspection and grade.	

NOTE 4: A drawing is included for parallel clamp screws. These screws can be made on either the engine lathe or the turret lathe or can be bought.

Unit No. *Operator's Job Title:* Milling Machine Operator

Project I *Project Name:* Parallel Clamps

Job No. 2 *Job Name:* Straight Clip *D.O.T. No.* 605.380

*Drawing Nos.*56, 59 *Time:* 1$\frac{1}{2}$ hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. End milling
2. Drilling
3. Center drilling

Equipment:
Vertical milling machine
Milling machine vise
$\frac{11}{32}$" end mill
Parallels
Wiggler
Center drill
No. 16 drill
Drill chuck
File

Materials:
CRS SAE 1020,
$\frac{1}{16}$" x $\frac{1}{2}$" x 1$\frac{1}{4}$"

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

NOTE: The operations shown on this sheet will produce a piece with the dimensions given in Ref. No. 3 of the table shown on the drawing. The instructor may, however, choose to make a piece to the dimensions of any other Ref. in the table.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select workpiece from those which have been laid out.	1. Layout is to be done at the layout bench or else use local shop procedure.
2. Set up a milling machine vise with its jaws parallel to the T-slots of the machine table.	2. Clean the vise base and the machine table before setting up. Use the swivel base dial readings in setting up.
3. Tighten an $\frac{11}{32}$" end mill in a milling machine collet and set the spindle speed.	3. Use the formula $\text{r.p.m.} = \frac{4(CS)}{D}$
4. Mill one end of the workpiece to length by clamping it with one end parallel to the top of the vise jaw. Then mill to the line.	4. CAUTION: Use light feed and a light depth of cut.
5. Repeat step 4 at the other end of the piece, milling to the 1$\frac{1}{8}$" dimension.	

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
6. Set one end of the piece on a parallel and tighten the vise jaw.	6. Do not use excessive pressure or the workpiece will buckle.
7. Locate cutter for slot F and mill to finished length.	7. Use the edge pickup method, moving the piece half the cutter width plus half the workpiece width. Use a soft piece of metal as a parallel.
8. Position spindle over location of hole G.	
9. Set up a drill chuck and center drill hole location G.	9. Use a proper spindle speed and clean drill chuck shank.
10. Drill hole G with a No. 16 drill.	10. CAUTION: Do not drill into parallels.
11. Deburr and file.	11. Use a hand file.
12. Submit for inspection and grade.	12. Clean all tools and machine. Return all tools to proper locations.

Unit No. *Operator's Job Title:* Milling Machine Operator

Project II *Project Name:* Parallels

Job No. 1A *Job Name:* Parallels (inches) *D.O.T. No.* 605.380

Drawing No. 50A *Time:* 6 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Setting up
2. Slab milling
3. Slot milling
4. Side milling

Equipment:
Horizontal milling machine
Side milling cutter, $\frac{3}{8}$" wide
Parallels
Helical slab milling cutter
1" micrometer
Dial indicator
Solid square
File
Bench vise
12" rule
Small sheet of paper

Materials:
2 pieces CRS SAE 1020,
$\frac{5}{8}$" x $\frac{7}{8}$" x $6\frac{1}{4}$"

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

NOTE 1: The job described below (No. 1A) provides for producing workpieces measured conventionally (that is, in inches). Another sheet describes Job 1B which provides for producing essentially the same pieces (parallels) in metric dimensions (that is, millimeters). In both jobs angles are measured in degrees and screw threads and hole diameters are also in conventional measurements.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select stock and deburr.	1. Use a bench vise.
2. Set up a 1" wide helical slab milling cutter and a vise.	2. Set the vise so the jaws are parallel to the machine table. Use an indicator.
3. Clamp one of the workpieces in the vise and set the table elevation to take a $\frac{1}{32}$" cut on surface A.	3. Use the paper feeler method to zero in the table elevation. Be sure to check clearance between overarm support and vise or workpiece. Use suitable parallels.
4. Remove workpiece from vise on completion of cut, return table to starting position, and remove burrs.	4. Use rapid traverse. Clean the vise of all chips.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
5. Repeat steps 3 and 4 on the second workpiece.	
6. Turn the workpiece over end for end on the parallels with surface A down, and mill surface B to arrive at .780" thickness.	6. Use a 1" micrometer for measurement.
7. Remove the workpiece and return the table to the starting position.	7. Use the rapid traverse. Clean the vise of all chips.
8. Repeat steps 6 and 7 on the second workpiece.	
9. Set up a workpiece with surface C facing upward in the vise, zero the table elevation, and mill surface C to clean up.	9. Again use the paper feeler method to zero in the table elevation.
10. Remove the workpiece from the vise on completion of the cut and return the table to the starting position. Remove all burrs.	10. Clean the vise.
11. Repeat steps 9 and 10 for the second piece.	
12. Place one piece back in the vise, turning it over end for end.	12. This will assist in keeping the workpiece parallel.
13. Set to depth and cut surface D to arrive at .530" thickness.	13. Use a 1" micrometer.
14. Repeat steps 12 and 13 on the second piece.	
15. Set up a $\frac{3}{8}$" side milling cutter and cut the $\frac{3}{8}$" x $\frac{1}{8}$" slot through the length of the workpiece.	15. Zero the cutter on the side of the workpiece with paper. Move the table in half the width of the workpiece and cutter together, plus the thickness of the paper.
16. Remove the workpiece from the vise, deburr it and turn it over end for end.	
17. Repeat steps 15 and 16 on the other slot.	
18. Set up the second workpiece and repeat the steps necessary to complete the $\frac{3}{8}$" x $\frac{1}{8}$" slots.	
19. Set and indicate the vise jaws at right angles to the milling machine table.	19. Always indicate the solid jaw.
20. Set up the workpiece on suitable parallels, extend it $\frac{3}{8}$" beyond the end of the vise, and machine the end to clean up. Remove all burrs.	20. Be sure to check the clearance between overarm support and the vise or workpiece.
21. Repeat steps 19 and 20 on the second workpiece.	
22. Set up and mill the opposite ends of both pieces to $6\frac{1}{32}$".	22. Machine both pieces together. Be sure both pieces

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
	are free of burrs before clamping in vise. Use a 12" rule.
23. Remove all burrs and submit for inspection and grade.	23. Clean all tools and the machine. Return tools to proper locations.

Unit No. *Operator's Job Title:* Milling Machine Operator

Project II *Project Name:* Parallels

Job No. 1B *Job Name:* Parallels (millimeters) *D.O.T. No.* 605.380

Drawing No. 50B *Time:* 6 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Setting up
2. Slab milling
3. Slot milling
4. Side milling

Equipment:
- Horizontal milling machine
- Side milling cutter, 10 mm. wide
- Parallels
- Helical slab milling cutter
- Metric micrometer, 0-25 mm.
- 15 cm. metric scale
- Metric dial indicator, 0-25mm.
- Magnetic Base
- Small sheet of paper
- Bench vise
- Solid square
- File

Materials:
2 pieces CRS SAE 1020,
16 mm. x 22 mm. x 152 mm.
($\frac{5}{8}$" x $\frac{7}{8}$" x $6\frac{1}{4}$")

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

NOTE: The job described below (No. 1B) will produce two pieces essentially the same as those produced by Job 1A. In Job 1B, however, the pieces have been designed in metric dimensions. In both jobs angles are measured in degrees and screw threads and hole diameters are also generally in conventional measurements.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select stock and deburr.	1. Use a bench vise.
2. Set up a 1" wide helical slab milling cutter and a vise.	2. Set the vise so the jaws are parallel to the machine table. Use an indicator. Always indicate the solid jaw.
3. Clamp one of the workpieces in the vise and mill surface A to clean up.	3. Use the paper feeler method to zero in the table elevation. Be sure to check clearance between overarm support and vise or workpiece. Use suitable parallels.

PROCEDURE	TECHNIQUES AND RELATED INFO.
4. Take workpiece out of vise on completion of cut and remove burrs. Return table to starting position.	4. Use rapid traverse. Clean the vise of all chips.
5. Repeat steps 3 and 4 on second workpiece.	
6. Turn the workpiece over end for end on the parallels, with surface A down, and mill surface B to 20.0 mm.	6. Use metric micrometer for measurement. 1.0 mm. is left oversize for grinding.
7. Remove the workpiece and return the table to the starting position.	7. Use the rapid traverse. Clean the vise of all chips.
8. Repeat steps 6 and 7 on the second workpiece.	
9. Set up a workpiece with surface A against solid jaw of the vise, zero the table elevation, and mill surface C to cleanup.	9. Again use the paper feeler method to zero in the table elevation.
10. Remove the workpiece from the vise, return the table to the starting position, and remove all burrs.	10. Clean the vise. Check workpiece for squareness. Use solid square.
11. Repeat steps 9 and 10 for second piece.	
12. Place one piece back in the vise, with surface B against solid jaw and last unmachined surface upward.	12. This will assist in keeping opposite surfaces of the workpiece parallel.
13. Mill thickness to 14.0 mm.	13. Use metric micrometer for measurement. 1.0 mm. is left oversize for grinding.
14. Repeat steps 12 and 13 on the second piece.	
15. Remove the helical slab milling cutter and set up a 10 mm. side milling cutter.	15. Be sure all arbor collars and the cutter are clean.
16. Mill the 10 mm. x 3.5 mm. slot through the length of the workpiece.	16. Zero the cutter on the side of the workpiece with paper. Set metric indicator on knee of machine. Move the table in half the width of the workpiece and cutter together, plus the thickness of the paper. Set metric indicator on machine column to get 3.5 mm. depth.
17. Remove the workpiece from the vise, take off all burrs and sharp edges, and repeat step 16 on the second slot.	
18. Set up the second workpiece and repeat steps 16 and 17 to complete the 10 x 3.5 mm. slots.	
19. Set and indicate the vise jaws at right angles to the milling machine table.	19. Always indicate the solid jaw.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
20. Set up the workpiece on suitable parallels, extend it 10 mm. beyond the end of the vise, and machine the end to clean up. Remove all burrs.	20. Be sure to check the clearance between overarm support and the vise or workpiece.
21. Repeat step 20 on the second workpiece.	
22. Set up and mill the opposite ends of both pieces to 150 mm.	22. Machine both pieces together. Be sure both pieces are free of burrs before clamping in vise.
23. Remove all burrs and submit for inspection and grade.	23. Clean all tools and the machine. Return all tools to proper locations.

Unit No. *Operator's Job Title:* Milling Machine Operator

Project III *Project Name:* Tap Wrench

Job No. 1 *Job Name:* Tap Wrench Body *D.O.T. No.* 605.380

Drawing No. 21 *Time:* 2 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Slitting
2. Indexing
3. Setting up

Equipment:
Vertical milling machine
$\frac{1}{16}$" slitting saw
Dividing head
$\frac{3}{4}$" collet
Stub arbor

Materials:
1 piece CRS SAE 1020,
$\frac{3}{4}$" x 2$\frac{7}{8}$"
machined on the lathe

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select wrench body machined on the lathe.	1. Check all sizes for accuracy.
2. Set up a $\frac{1}{16}$" slitting saw.	2. Use a stub arbor.
3. Set up a dividing head in a horizontal position.	3. Clean the machine table and the dividing head base.
4. Clamp the workpiece horizontally using a $\frac{3}{4}$" collet.	4. Extend workpiece far enough so the cutter will not hit the collet.
5. Position the cutter for cutting one slot.	5. Review centering procedures.
6. Cut one slot.	6. Break through to the $\frac{1}{4}$" hole and mill to 2" length. Use cutting oil.
7. Index 90° and cut second slot.	
8. Repeat until the four slots are completed.	
9. Remove from the dividing head and deburr.	
10. Submit for inspection and grade.	

Unit No. *Operator's Job Title:* Milling Machine Operator

Project IV *Project Name:* Drill Stand

Job No. 1 *Job Name:* Drill Stand *D.O.T. No.* 605.380

Drawing No. 42 *Time:* 5 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Setting up
2. Face milling

Equipment:
Vertical milling machine
Vise
Vernier calipers
Fly cutter
Clamps
Angle plate
Solid square
T-bolts
Straps and step blocks

Materials:
1 piece cast aluminum
$1\frac{3}{4}$" x $3\frac{1}{8}$" x $6\frac{1}{4}$"

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select stock and remove all burrs.	
2. Set up a milling machine vise on a vertical milling machine.	2. Clean all bearing surfaces. Indicate vise jaws parallel to table T-slots.
3. Set up a fly cutter.	3. Set blade to swing a $3\frac{1}{4}$" dia.
4. Set up the workpiece in the vise and mill side A.	4. Set side D against the solid jaw and side B down.
5. Remove from the vise.	5. Remove all burrs and clean the vise.
6. Place in vise and mill side C.	6. Set side A against solid jaw and side D down.
7. Remove from the vise.	7. Clean the vise and remove all burrs.
8. Reset in vise and mill side B to $3\frac{1}{32}$" width.	8. Set side C against solid jaw and side A down. Use vernier calipers to check size.
9. Remove from the vise.	9. Clean the vise and remove all burrs.
10. Replace in vise and mill side D to $1\frac{7}{32}$".	10. Set side A against the solid jaw with side C down. Use vernier calipers to check size.

PROCEDURE	TECHNIQUES AND RELATED INFO.
11. Remove piece from vise and deburr.	11. Clean the vise.
12. Remove the vise from the machine.	12. Clean the table.
13. Set up an angle plate to mill surfaces E and F.	13. Use T-bolts, straps and step blocks.
14. Mill surfaces E and F to $6\frac{1}{32}$" length.	14. Use clamps for holding. Use solid square to aline with machine table.
15. Remove all burrs and submit for inspection and grade.	15. Clean all tools and machine. Return all tools to proper places.

Unit No. *Operator's Job Title:* Milling Machine Operator
Project V *Project Name:* 1-2-3 Block
Job No. 1 *Job Name:* 1-2-3 Block *D.O.T. No.* 605.380
Drawing No. 45.1 *Time:* 8 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Setting up
2. Plain milling
3. Mill sawing
4. End milling

Equipment:
Horizontal milling machine
Slab milling cutter
Milling vise
Solid square
2" micrometer
3" micrometer
4" micrometer
Parallels
$\frac{1}{8}$" mill saw
Shell end mill

Materials:
1 piece CRS SAE 1020,
$1\frac{1}{4}$" x $2\frac{1}{4}$" x $6\frac{3}{4}$"

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select stock and deburr.	
2. Set up a plain milling cutter and a vise.	2. Set vise and cutter as close to column as possible. Indicate the vise jaws parallel to the table T-slots.
3. Tighten workpiece in vise with surface C down.	
4. Mill surface D.	4. Remove approximately $\frac{1}{8}$".
5. Remove from the vise and deburr.	5. Clean the vise of all chips.
6. Replace the workpiece in the vise with surface D against the solid jaw and B down, and machine surface A.	
7. Machine surface A.	7. Remove approximately $\frac{1}{8}$".
8. Remove from the vise and deburr.	8. Machined surface must be square. Use a solid square.
9. Set the workpiece on a set of parallels with surface D down and surface A against the solid jaw.	9. Be sure piece is seated against the parallels.
10. Mill surface C to 1.020".	10. Use a 1" to 2" micrometer.
11. Remove from the vise and deburr.	

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
12. Check the piece for squareness.	
13. Position workpiece with surface D against the solid jaw and A down.	
14. Mill surface B to 2.020".	14. Use a 2" to 3" micrometer.
15. Remove from the vise and deburr.	
16. Turn the vise 90°.	16. Indicate solid jaw parallel to spindle.
17. Remove slab mill and mount a $\frac{1}{8}$" mill-saw.	17. Clean the arbor and all collars.
18. Lay out a line in the center of the workpiece length.	18. Use a combination square and a scriber.
19. Mill-saw piece in half.	19. Keep surface A against solid jaw.
20. Remove piece from vise and deburr both pieces.	
21. Remove the mill-saw and the arbor.	
22. Set up a shell end mill.	22. Clean the spindle hole and the adapter. Be sure the cutter is tight.
23. Set the workpiece in the vise with surface A against the solid jaw and D down.	23. Set on a suitable pair of parallels and be sure workpiece is seated.
24. Mill to clean up surface E.	
25. Repeat steps 2 through 24 on the second piece.	25. Keep surface A against the solid jaw.
26. Turn piece end for end and mill surface F to 3.020".	
27. Repeat step 26 on the second piece.	
28. Submit for inspection and grade.	28. Clean all tools and machine. Return all tools to proper places.
29. Send the pieces to the drill press area for the drilling operations.	

Unit No. *Operator's Job Title:* Milling Machine Operator

Project VI *Project Name:* T-Nut

Job No. 1 *Job Name:* T-Nut *D.O.T. No.* 605.380

Drawing No. 62 *Time:* 4 hours

Performance Objectives:

Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:

1. Plain milling
2. Straddle milling
3. Mill sawing
4. Side milling
5. Setting up

Equipment:

Horiz. milling machine
Milling mach. vise
Parallels
Set of staggered tooth side milling cutters $\frac{3}{8}$" wide
0-1" micrometer
Vernier calipers
Dial indicator
File
Mill-saw
Plain side milling cutter

Materials:

1 piece CRS SAE 1020,
$\frac{3}{4}$" x $1\frac{1}{4}$" x $8\frac{3}{16}$"
(To make 5 T-nuts)

Selected references:

Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select stock and remove all burrs.	
2. Set up vise on milling machine table with jaws parallel to the T-slots.	2. Use a dial indicator for final setting.
3. Clamp the workpiece in the vise with the $1\frac{1}{4}$" face up.	3. Use a suitable set of parallels to raise the workpiece to a workable height.
4. Set up a pair of $\frac{3}{8}$" staggered tooth straddle milling cutters.	4. Use a $\frac{11}{16}$" spacer bushing between the two cutters.
5. Set to depth and cut to $\frac{9}{32}$".	5. Use the paper feeler method.
6. Center the cutter so that the $\frac{11}{16}$" dimension is in the center of the $1\frac{1}{4}$" width.	6. Bring the side edge of the cutter against the inside edge of the workpiece and zero the dial. Move the table in the width of the cutter, plus $\frac{11}{16}$" plus width of the step.
7. Mill through the workpiece.	
8. Remove the workpiece from the vise.	8. Remove all burrs.
9. Swivel the vise 90° so the vise jaws are at right angles to the T-slots.	9. Indicate the solid jaw.

PROCEDURE	TECHNIQUES AND RELATED INFO.
10. Mount a plain side milling cutter.	10. Keep the cutter close to the column.
11. Clamp the workpiece in the vise flat with $\frac{1}{2}$" extended over the end of the vise.	
12. Machine the end of the piece to clean up.	
13. Reverse part in vise and mill to 8" length.	
14. Remove the plain side milling cutter and mount a $\frac{1}{8}$" mill-saw.	14. Be sure to select a mill-saw that will have at least 3 teeth in contact with the work thickness.
15. Extend the workpiece $1\frac{3}{4}$" from the end of the vise. Set up a work stop and locate the mill-saw so a workpiece will be cut off to $1\frac{1}{2}$" length.	
16. Cut off the remaining 4 pieces by sliding the workpiece out to the stop for each cut.	16. Be sure to use a $1\frac{1}{4}$" spacer at the opposite end of the vise when the workpiece becomes short.
17. Remove all burrs and submit for inspection and grade.	17. Clean all tools and the machine. Return all tools to proper locations.

Unit No. *Operator's Job Title:* Milling Machine Operator

Project VII *Project Name:* Bench Vise

Job No. 1 *Job Name:* Fixed and Movable Jaws *D.O.T. No.* 605.380

Drawing Nos. 15, 17 *Time:* 6 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawings in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Face milling
2. Drilling
3. Setting up
4. Angular milling

Equipment:
Vertical milling machine
Vise
Drill chuck
$1\frac{1}{2}$" shell end mill
Center drill
$\frac{3}{16}$" drill
Indicator
Parallels
Surface gage

Materials:
1 piece CRS SAE 1020,
$1\frac{1}{4}$" x $1\frac{1}{2}$" x $7\frac{3}{16}$"
from engine lathe operation

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select workpiece from engine lathe operation.	1. Check all dimensions before proceeding on the milling machine.
2. Set up a milling machine vise on a vertical mill.	2. Clean table and vise. Indicate vise jaw parallel to the T-slots.
3. Set up and locate to drill the two $\frac{3}{16}$" holes.	3. Set the workpiece flat in the vise on parallels, with the widest flat surface down. Set up a drill chuck and center drill in the spindle. The first hole is located in the center of the $1\frac{1}{2}$" width and $\frac{9}{16}$" in from the threaded end. Follow shop practice to determine location.
4. Drill the first $\frac{3}{16}$" hole.	4. Use a center drill to spot the location prior to drilling the hole.

PROCEDURE	TECHNIQUES AND RELATED INFO.
5. Drill the second $\frac{3}{16}$" hole.	5. Obtain location by moving the table longitudinally $2\frac{7}{8}$".
6. Remove the workpiece and deburr.	
7. Set up to center drill the location for the .500" reamed holes and the $\frac{27}{64}$" tapped hole.	7. Replace workpiece flat in the vise so the surface with the $\frac{3}{16}$" holes is against the fixed jaw of the vise.
8. Center drill the first reamed hole.	8. By using standard shop practice, locate the center drill in the center of $1\frac{1}{4}$" width and $1\frac{1}{4}$" from the unthreaded end.
9. Center drill for the tapped hole.	9. Move table longitudinally 1" for proper positioning.
10. Center drill for the second reamed hole.	10. Move the longitudinally 1" for positioning.
11. Remove from the vise and send to the drill press for drilling, reaming, and tapping; then to bench for laying out and to the bandsaw for parting of the two jaws.	
12. When the piece is returned to the milling machine, set up and mill the two sawed surfaces.	12. Place a $1\frac{1}{2}$" shell end mill in the spindle of the vertical mill. Place workpiece flat in the vise with the sawed surface up. Mill to clean up. Repeat the operation on second piece.
13. Mill the relief surface on both pieces.	13. Using the same setup as in step 12, mill the relief surface to a depth of $\frac{1}{16}$" on one piece. Repeat the operation on the second piece.
14. Remove workpiece from vise and take off all burrs.	
15. Set up to mill the angular surfaces on one piece.	15. Place workpiece in the vise with the angular layout line level with and slightly above the top of the vise jaw. Use surface gage to set layout line level.
16. Mill angular surface.	16. Mill to the layout line.
17. Set up and mill the angular surface on the second workpiece.	
18. Remove workpiece and deburr both pieces.	
19. Submit for inspection and grade.	

Unit No. *Operator's Job Title:* Milling Machine Operator

Project VIII *Project Name:* Surface Gage

Job No. 1 *Job Name:* Base *D.O.T. No.* 605.380

Drawing Nos. 25, 25.1 *Time:* 6 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawings in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Setting up
2. Plain milling
3. Slotting
4. Angular milling

Equipment:
Horizontal milling machine
Swivel vise
$\frac{3}{8}$" plain milling cutter
Side milling cutter
Combination square
Protractor
Parallels
Vernier calipers
Solid square
Dial indicator
Depth micrometer
File

Materials:
1 piece CRS SAE 1020,
$1\frac{1}{8}$" x $1\frac{1}{8}$" x $2\frac{7}{8}$"

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*

NOTE: The drawings for the two jobs (Base and Adjustment Bar) in this project show dual dimensions (that is, both inches and millimeters). This has been done to familiarize students with metric measurements and with dual dimensioning. The instructor can decide whether he would like the students to use inches or millimeters in producing the two pieces.

1. Select stock and deburr.	
2. Set up a milling vise with the jaws parallel to the table T-slots.	2. Clean the table and the vise base before mounting the vise. Use washers under the locking nuts.
3. Set up a plain milling cutter.	3. Set the cutter on the arbor as close to the machine column as allowable.
4. Tighten the workpiece in the vise on parallels.	4. Raise the workpiece no higher than necessary.
5. Mill the .940" dimension to .960".	5. The .020" oversize is allowance for finish grinding.

PROCEDURE	TECHNIQUES AND RELATED INFO.
6. Mill the bottom width to 1.020".	
7. Swivel the vise 90°.	7. Review method of squaring with a solid square.
8. Mount a $\frac{3}{8}$" side milling cutter.	8. Use a cutter large enough to clear the arbor support.
9. Clamp the workpiece in the vise with end extending $\frac{1}{2}$".	9. Set on a suitable set of parallels.
10. Mill one end square and to clean up.	
11. Reverse workpiece in the vise.	11. Remove all burrs and sharp edges.
12. Mill the opposite end to 2.840".	12. Use vernier calipers for sizing.
13. Remove the workpiece from the vise.	13. Take off all burrs and sharp edges.
14. Set the vise with the jaws parallel to the T-slots.	14. Use the dial indicator to aline the jaws.
15. Clamp the workpiece in the vise on suitable parallels.	
16. Aline the cutter to cut the .460" slot.	16. Touch the side of the cutter to the side of the workpiece. Move the table in the thickness of the cutter plus the thickness of the workpiece wall plus .005".
17. Set the depth of cut for .670" and mill slot through piece.	17. Set the table elevation by the paper touch-off method. Use a depth micrometer to check the depth.
18. Return the cutter to the beginning and move table over to machine the slot to .450" width.	18. Move the table the difference between .450" and the width of the cutter.
19. Remove the workpiece from the vise.	19. Take off all burrs and sharp edges.
20. Swivel the vise 90°.	20. Use a solid square to aline it.
21. Set up the workpiece at a 15° angle and tighten in the vise.	21. Use vernier protractor.
22. Mill the 15° angle to .680". Use a slab milling cutter.	22. The .010" extra is for grinding.
23. Remove piece from the vise; take off all burrs and sharp edges.	
24. Reset in the vise and mill the remaining angle to 11°.	24. Leave .010" for finish grinding on the 11° angle.
25. Deburr and submit for inspection and grade.	

Unit No. *Operator's Job Title:* Milling Machine Operator

Project VIII *Project Name:* Surface Gage

Job No. 2 *Job Name:* Adjustment Bar *D.O.T. No.* 605.380

Drawing Nos. 25, 25.2 *Time:* 3 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Plain milling
2. Step milling
3. Setting up
4. Side milling

Equipment:
Horizontal milling machine
Swivel vise
$\frac{3}{4}$" side milling cutter
1" micrometer
2-3" micrometer
File

Materials:
CRS SAE 1020,
$\frac{1}{2}$" x $\frac{1}{2}$" x 3"

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

NOTE: The drawings for the two jobs (Base and Adjustment Bar) in this project show dual dimensions (that is, both inches and millimeters). This has been done to familiarize students with metric measurements and with dual dimensioning. The instructor can decide whether he would like the students to use inches or millimeters in producing the two pieces.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select stock and deburr.	
2. Set up a $\frac{3}{4}$" side milling cutter.	
3. Set up a swivel vise with jaws parallel to the T-slots of machine table.	
4. Mill the .460" dimension to .480".	4. The .020" extra will be for finish grinding.
5. Remove workpiece from the vise and take off all burrs.	
6. Mill the .440" dimension to .460".	6. The .020" extra will be for finish grinding.
7. Remove the workpiece from the vise and remove all burrs.	

PROCEDURE	TECHNIQUES AND RELATED INFO.
8. Swivel the vise 90°.	
9. Set up workpiece and mill one end clean and square.	9. Set piece on a suitable parallel and extend it ½" beyond vise jaws.
10. Remove from vise and deburr.	10. Clean the vise and parallel.
11. Mill second end to 2.820".	
12. Mill the .500" x .220" step.	12. Leave .010" on each surface of the step for finish grinding.
13. Remove the workpiece from the vise and deburr.	
14. Submit for inspection and grade.	14. Clean all tools and machine. Return all tools to proper locations.

Unit No. *Operator's Job Title:* Milling Machine Operator

Project IX *Project Name:* Fly Tool Face Cutter

Job No. 1 *Job Name:* Fly Tool Face Cutter *D.O.T.* ~~*No.*~~ 605.380

Drawing No. 8 *Time:* 6 hours

Performance Objectives:
Using only the equipment, materials and operations listed here, the student will be able to produce the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Setting up
2. Plain milling
3. Slotting
4. Step milling

Equipment:
Horizontal milling machine
Dividing head
2" slab milling cutter
$\frac{5}{16}$" side milling cutter

Materials:
1 piece CRS
2" x $2\frac{11}{16}$" machined on engine lathe

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select stock machined on the lathe.	1. Check all measurements before further machining.
2. Set up the slab milling cutter on the horizontal milling machine.	2. Set the cutter as close to the column as possible. Set the cutter rotation so the rotational forces are tightening the chuck on the dividing head.
3. Set up a dividing head with a chuck and tilt to 15° from the vertical. Clamp the .623" shank of the workpiece.	
4. Mill the 15° angular surface to $1\frac{3}{16}$" dimension.	
5. Set up and locate the $\frac{5}{16}$" side milling cutter.	5. Locate by paper feeler method.
6. Mill the .320" slot to $\frac{5}{16}$" depth.	6. Move the table over if necessary to get .320" slot. Use vernier calipers to measure.
7. Mill the $\frac{9}{16}$" ledge to $\frac{5}{16}$" depth.	
8. Remove all burrs and send to drill press for setscrew holes.	
9. Submit for inspection and grade.	9. Clean all tools and machine. Return all tools to proper places.

Unit No. *Operator's Job Title:* Milling Machine Operator

Project X *Project Name:* Arbor Press

Job No. 1 *Job Name:* Base *D.O.T. No.* 605.380

Drawing Nos. 27, 33 *Time:* 7 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawings in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Plain milling
2. Slotting
3. Angular milling
4. Chamfering

Equipment:
Horizontal milling machine
Vise
Solid square
Vernier calipers
Interlocking slotting cutter
Plain helical cutter
45° angular cutter
Protractor

Materials:
1 piece CRS SAE 1020
1" x 3" x 3½"

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	TECHNIQUES AND RELATED INFO.
1. Select stock and deburr.	
2. Set up a plain helical cutter.	2. Observe safety rules: use a rag when handling the cutter.
3. Set up a milling vise with the jaws set parallel to the T-slots of the machine table.	3. Use a solid square to aline the jaws with the workpiece.
4. Square one end of the 3¼" dimension to clean up.	4. Calculate feeds and speeds.
5. Remove piece from vise.	5. Deburr and clean the vise.
6. Mill the opposite surface to 3¼" dimension.	
7. Have the piece laid out, drilled, and sawed.	
8. Deburr the workpiece and check the layout.	
9. Set the vise jaws parallel to the machine spindle.	9. Use a solid square to aline vise jaws.
10. Set up a pair of interlocking slotting cutters.	10. Keep cutter as close to the machine column as possible.
11. Mill the ¾" x ⅞" slot.	11. Use vernier calipers to measure.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
12. Remove from vise and deburr.	
13. Reset in vise and mill the 1" x 1" slot.	13. Leave .020" for grinding.
14. Remove from vise and deburr.	
15. Remove the cutters.	15. Clean the cutters, using a rag to handle them.
16. Swivel the vise jaws to be parallel to T-slots.	16. Aline them, using a dial indicator.
17. Mount a plain helical milling cutter.	
18. Set up workpiece at a 53° angle.	18. Use a protractor.
19. Mill one of the angles.	19. Leave $\frac{1}{64}$" for grinding.
20. Set up and mill the second 53° angle.	20. Leave $\frac{1}{64}$" for grinding.
21. Remove the plain milling cutter and mount a 45° angle cutter.	
22. Cut the 45° chamfer completely around the perimeter of the workpiece.	
23. Remove all burrs and submit for inspection and grade.	23. Clean all tools and the machine. Return all tools to their proper places.

Unit No. *Operator's Job Title:* Milling Machine Operator

Project X *Project Name:* Arbor Press

Job No. 2 *Job Name:* Column *D.O.T. No.* 605.380

Drawing Nos. 27, 32 *Time:* 12 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawings in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Fly cutting
2. Slotting
3. Drilling
4. Counterboring
5. Reaming
6. Radius milling
7. Setting up
8. Face milling

Equipment:
- Vertical milling machine
- Vise
- Solid square
- Dial indicator
- Fly cutter
- $\frac{1}{2}$" corner-radius end mill
- Counterbore
- Vernier calipers
- Center drill
- $\frac{31}{64}$" drill
- Parallels
- $\frac{1}{2}$" reamer
- Drill chuck
- Hold-downs
- Stops
- 4-fluted end mill

Materials:
1 piece HRS SAE 1020,
$1\frac{1}{4}$" x $3\frac{1}{2}$" x $6\frac{1}{4}$"

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	TECHNIQUES AND RELATED INFO.
1. Select stock and deburr.	
2. Clamp workpiece to table with $3\frac{1}{4}$" x 6" surface down on table.	2. Use hold-downs and stops.
3. Set up a suitable fly cutting tool.	
4. Fly cut $\frac{1}{16}$" from entire surface.	4. Be sure to take off all scaled surface even if this requires going deeper than $\frac{1}{16}$".
5. Turn workpiece over and machine opposite side to 1.000".	5. Use hold-downs and stops.
6. Set up a milling vise.	
7. Set up the workpiece and mill the 1" x $6\frac{1}{4}$" surface.	7. Remove all burrs.
8. Remove piece from vise, turn end for end, set up and mill opposite surface to 3.250" height.	8. Remove burrs. Use vernier calipers to measure.
9. Remove from vise and deburr.	9. Clean the vise.
10. Aline the vise jaws parallel to the T-slots.	10. Use a dial indicator.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
11. Set up an end mill.	11. Use a 4-lip end mill.
12. Mill one end of 6" length clean and square.	12. Lay workpiece flat in the vise on suitable parallels. Lock the table longitudinal clamp after setting the depth of cut; use cross-feed travel.
13. Remove from vise and deburr.	13. Clean the vise.
14. Replace in vise and mill opposite side to 6.000".	14. Measure with vernier calipers.
15. Replace end mill with a drill chuck.	
16. Locate the .500" x 1.168" counterbore.	16. Use an edge finder or local shop practice.
17. Center drill, drill, and ream.	
18. Counterbore hole to 1.168" x $\frac{47}{64}$" depth.	18. Use a fly tool type of counterbore set to the diameter. CAUTION: Be sure to counterbore work on the correct side.
19. Locate the $\frac{1}{4}$" inner corner radius and drill $\frac{1}{2}$" hole.	19. Use table graduations to locate.
20. Remove from the vise and deburr.	20. Clean the vise. Send piece for benching, drill press, and sawing operations.
21. Remove the burrs and set in the vise to mill $\frac{7}{16}$" x .625" slot.	21. Leave .005" on depth and sides for grinding. Use a $\frac{3}{8}$" diameter end mill. Keep slot centrally located.
22. Set up a fly cutter and mill the 1" x 4" inner wall to 1.000" height.	22. Set the table stop to avoid hitting the vertical wall.
23. Remove from vise and deburr.	
24. Set piece back in vise with 1" x $3\frac{1}{4}$" surface down.	
25. Mill the 1" x $2\frac{1}{4}$" inner surface to 2.000".	25. Set table stops to avoid hitting wall.
26. Reset workpiece in vise to mill corner radius. Remove burrs.	26. Clean vise.
27. Mill the $\frac{1}{2}$" outer radius.	27. Use a $\frac{1}{2}$" concave corner-radius end mill.
28. Remove from vise and submit for inspection and grade.	28. Clean all tools and machine. Return all tools to proper locations.

Unit No. *Operator's Job Title:* Milling Machine Operator

Project X *Project Name:* Arbor Press

Job No. 3 *Job Name:* Cover Plate *D.O.T. No.* 605.380

Drawing Nos. 27, 30 *Time:* 2 hours

Performance Objectives

Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawings in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:

1. Setting up
2. End milling

Equipment:

Vertical milling machine
Milling Vise
Indicator
Solid square
Vernier calipers

Materials:

1 piece CRS
$\frac{1}{4}$" x 1" x $2\frac{1}{4}$"

Selected references:

Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select stock and deburr.	
2. Set up end mill and vise.	2. Indicate the vise.
3. Square one end of 2" length to clean up and remove burrs.	3. Lay workpiece flat in the vise on suitable parallels. Extend the piece $\frac{1}{2}$" from the vise jaws.
4. Reverse the workpiece and mill to 2" length.	
5. Remove all burrs and submit for inspection and grade.	5. Clean all tools and machine. Return all tools to proper locations.

Unit No. *Operator's Job Title:* Milling Machine Operator

Project X *Project Name:* Arbor Press

Job No. 4 *Job Name:* Table *D.O.T. No.* 605.380

Drawing Nos. 27, 29 *Time:* 6 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawings in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Setting up
2. Slotting
3. Indexing

Equipment:
- Vertical milling machine
- Turntable
- .250" center plug
- T-slot bolts
- flat clamps
- $\frac{1}{4}$", $\frac{3}{8}$", $\frac{1}{2}$", and $\frac{5}{8}$" end mills
- Dial indicator

Materials:
1 piece CRS SAE 1020, 2" dia. x $\frac{1}{2}$" thick from engine lathe operation

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select material from drill press.	1. Check all sizes before proceeding with milling machine operations.
2. Set up a turntable on a vertical milling machine.	2. Clean the milling machine table and the base of the turntable.
3. Aline the centers of the turntable and the machine spindle.	3. Set a dial indicator in the machine spindle and indicate the center hole of the turntable until you have equal readings at 4 points 90° apart.
4. Set a .250" locating plug in the center hole of the turntable.	4. Clean the hole in the turntable before inserting plug.
5. Select clamps and bolts.	5. Use bolts and clamps that will not interfere with locating the slots to be milled.
6. Aline the layout lines of the $\frac{5}{8}$" slot with the zero line on the turntable graduating dial; clamp the workpiece to the table on parallels.	6. Use a solid square to make the alinement. Bank the square against the machine column.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
7. Mill the $\frac{5}{8}$" slot to size.	7. Use the cross-slide to feed the work. CAUTION: Do not mill beyond a point $\frac{19}{32}$" from center of workpiece, as marked on drawing.
8. Change cutter to $\frac{1}{2}$" end mill.	
9. Index the turntable 90° and mill the $\frac{1}{2}$" slot to size.	9. Follow step 7, above.
10. Change cutter to $\frac{3}{8}$" end mill.	
11. Index turntable 90° and mill the $\frac{3}{8}$" slot to size.	11. Follow step 7.
12. Change cutter to $\frac{1}{4}$" end mill.	
13. Index turntable 90° and mill the $\frac{1}{4}$" slot to size.	13. Follow step 7.
14. Remove work from machine, deburr, and submit for inspection.	14. Clean all tools and machine. Return all tools to proper locations.

Unit No. *Operator's Job Title:* Milling Machine Operator

Project X *Project Name:* Arbor Press

Job No. 5 *Job Name:* Gear Shaft *D.O.T. No.* 605.380

Drawing Nos. 27, 28 *Time:* 6 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawings in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Setting up
2. Gear cutting

Equipment:
- Horizontal milling machine
- Dividing head and centers
- Dog
- Gear cutter
- Dial indicator
- Surface gage
- Vernier height gage
- Vernier gear tooth calipers

Materials:
1 piece CRS SAE 1020, 1.166" dia. x $2\frac{27}{32}$" from engine lathe operation

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select workpiece from engine lathe.	1. Check sizes before performing any additional operations.
2. Set up a dividing head and centers to hold work.	2. Clean all bearing surfaces. Calculate indexing for 12 teeth.
3. Select a suitable milling dog and set up workpiece.	3. Indicate workpiece until parallel to table. Use a surface gage and dial indicator. Be sure to lock dog in place.
4. Set up a $14\frac{1}{2}$° 12 D.P. No. 8 spur gear cutter.	4. Clean all collars and cutter surfaces.
5. Brush layout blue on 1.166" dia.	5. Set cutter rotation and feeds and speeds.
6. Layout center lines with a vernier height gage on the peripheral surface.	
7. Center the cutter with the layout line, after indexing the line to the top.	7. Touch work lightly with cutter and split the line. Use a magnifying glass.
8. Rough cut all teeth to .159" depth.	8. Leave .020" for a finishing cut. Lock all table slides not in motion.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
9. Finish cut all teeth to final depth of .179".	9. Explain reason for roughing and finishing cuts. NOTE: Depth of gear is the same as that of rack.
10. Deburr and submit for inspection and grade.	10. Clean all tools and machine. Return all tools to proper places.

Unit No. *Operator's Job Title:* Milling Machine Operator

Project X *Project Name:* Arbor Press

Job No. 6 *Job Name:* Rack *D.O.T. No.* 605.380

Drawing Nos. 27, 28 *Time:* 7 hours

Performance Objectives:
Using only the equipment, materials and operations listed here, the student will be able to produce the piece shown on the drawings in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Setting up
2. End milling
3. Angular milling
4. Rack gear cutting

Equipment:
Horizontal milling machine
Universal vertical milling head
Milling vise
Dial indicator
Solid square
File
End mills
45° angular cutter
Gear cutter
$\frac{3}{4}$" end mill

Materials:
1 piece HRS SAE C1020,
$\frac{5}{8}$" x $\frac{3}{4}$" x 5"

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select stock and deburr.	1. Check material size.
2. Set up a universal vertical head and indicate for squareness.	
3. Set up a vise with jaws parallel to machine spindle.	3. Clean all bearing surfaces.
4. Set up a $\frac{3}{4}$" end mill.	
5. Set up workpiece to machine surface A with surface B against solid jaw.	5. Take a cut deep enough to clean up.
6. Remove piece from vise and check for squareness.	6. Clean the vise and parallels.
7. Place side A against solid jaw and machine surface D.	7. Remove sufficient material to clean up. Check for squareness.
8. Place side A against solid jaw and machine surface B to $\frac{29}{64}$".	8. Leave $\frac{1}{64}$" for grinding.
9. Remove piece from the vise.	9. Clean the vise and parallels.
10. Place side B against the solid jaw and machine surface C to $\frac{5}{8}$".	
11. Remove from the vise and check for squareness.	11. Clean the vise and parallels.
12. Set up a 4-lip end mill and mill end E.	12. Extend workpiece $\frac{1}{2}$" beyond end of vise jaws.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
13. Remove from vise, deburr, and check for squareness.	
14. Place in vise and mill end F to finished size.	
15. Remove vertical head and set up a 45° cutter and arbor.	
16. Mill 45° chamfer to $\frac{1}{16}$" on all edges of end E.	
17. Set up a 12 D.P. No. 1 gear cutter.	
18. Center the cutter in from end E.	18. Measure in $\frac{1}{2}$" plus $\frac{1}{2}$ the width of the gear tooth and scribe a line.
19. Cut the rack with a linear pitch of .262" and a depth of tooth .179".	19. Use cross lead screw and maintain edge distances of $\frac{1}{2}$" and $\frac{3}{4}$". Use a rack-cutting attachment if available.
20. Remove all burrs and submit for inspection and grade.	20. Clean all tools and the machine. Return all tools to proper places.

Unit No. *Operator's Job Title:* Milling Machine Operator

Project XI *Project Name:* Precision Step Block

Job No. 1 *Job Name:* Precision Step Block *D.O.T. No.* 605.380

Drawing No. 44 *Time:* 10 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Setting up
2. Deep hole drilling
3. Countersinking
4. Counterboring
5. Slotting
6. Step milling
7. Face milling

Equipment:
Horizontal milling machine
Solid square
Vernier calipers
$\frac{1}{2}$" plain milling cutter
$\frac{1}{8}$" slitting saw
Drill chuck
Combination square
shell end mill
$\frac{5}{16}$" drill
Edge finder or
center finder
$\frac{7}{16}$" counterbore
90° countersink

Materials:
1 piece oil hardening steel
$1\frac{3}{4}$" x $1\frac{3}{4}$" x $1\frac{3}{4}$"

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select stock and deburr.	
2. Set up a milling machine vise with the jaws at right angles to the T-slots.	2. Indicate the vise with the solid jaw at the left side of the table. CAUTION: Be sure that the adapter locking screw is tight before taking a cut.
3. Set up a 3" shell end mill cutter.	
4. Lock the workpiece in the vise with surface B against the solid jaw and $\frac{1}{2}$" extending over the end of the jaws.	
5. Mill surface D to clean up.	5. Be sure to take a cut deep enough to get under the scale.
6. Remove from the vise and turn the piece around with side D against the solid jaw. Keep side A down.	6. Remove the burrs and clean the vise.
7. Mill side E to clean up.	
8. Remove the piece from the vise.	8. Remove all burrs and clean the vise. Check the workpiece with a solid square.

PROCEDURE	TECHNIQUES AND RELATED INFO.
9. Replace in vise with side D down and side E against the solid jaw.	
10. Mill side A to clean up.	
11. Remove from the vise.	11. Remove the burrs, clean the vise and check the piece with a solid square.
12. Replace piece in the vise with side A down and side E against the solid jaw, and mill surface C to 1.530".	12. Zero the crossfeed dial and set a stop against the workpiece in the vise. .030" is left for grinding.
13. Remove piece from vise.	13. Clean the vise, remove the burrs from the workpiece, and check the size and squareness.
14. Replace the workpiece in the vise with side E down and surface D against the solid jaw.	14. Be sure the workpiece is against the stop.
15. Mill surface F to size 1.530".	15. Check size before removing from the vise.
16. Remove from the vise.	16. Clean the vise and remove the burrs from workpiece.
17. Replace the workpiece in the vise with surface A down and surface C against the solid jaw.	
18. Mill surface B to 1.530". Remove from vise and deburr.	18. Check size before removing workpiece from vise.
19. Remove the shell end mill from machine spindle.	19. Clean the machine spindle.
20. Mount a drill chuck.	20. Clean the shank of the drill chuck.
21. Clamp an edge finder in the drill chuck.	21. NOTE: A center finder may be used instead.
22. Locate the center for the $\frac{5}{16}$" hole. Mount workpiece as in step 12.	22. Use local shop practice. Allow for the .015" grinding.
23. Center drill, then drill the $\frac{5}{16}$" hole through the workpiece.	23. Review deep hole drilling practices.
24. Counterbore to $\frac{7}{16}$" x $\frac{5}{16}$" deep.	24. Use the machine dials for control of depth.
25. Countersink $\frac{1}{16}$" deep x 45°.	25. Use same procedure as above.
26. Remove the workpiece from the vise.	26. Remove the burrs and clean up the vise.
27. Replace the workpiece in the vise keeping side F against the solid jaw and side B down.	27. Seat the piece against the stop.
28. Counterbore the $\frac{5}{16}$" hole from side D.	28. Machine to previous dial setting.
29. Countersink the $\frac{5}{16}$" hole from side D.	29. As in step 28 above.
30. Remove from the vise and deburr.	
31. Set up a $\frac{1}{2}$" wide milling cutter.	31. Select a cutter large enough in diameter to keep the arbor from rubbing on surface F.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
32. Set up workpiece with side C against the solid jaw of the vise and side A down.	
33. Mill surface G.	33. Locate cutter off side B and move it in the width of the cutter plus .405". Set depth for .375".
34. Mill surface H.	34. Move the work over .375" and set the depth another .375".
35. Mill surface I.	35. Move the table over .375" and set the depth for .375".
36. Remove the workpiece from the vise and take off all burrs.	
37. Set up the workpiece on a 45° angle, with side C against the solid jaw and side A at a 45° angle.	37. Use a protractor or a combination square.
38. Set up a $\frac{1}{8}$" wide mill-saw.	38. Use a cutter large enough in diameter to clear upper edges of surfaces F and E.
39. Mill $\frac{1}{8}$" x $\frac{1}{16}$" slot in each of the steps G, H, and I.	39. Calculate the set-over from the corner made by surfaces B and F.
40. Remove from vise and deburr.	
41. Submit for inspection and grade.	

Unit No. *Operator's Job Title:* Milling Machine Operator

Project XII *Project Name:* Precision Angle Plate

Job No. 1A *Job Name:* Precision Angle Plate (inches) *D.O.T. No.* 605.380

Drawing No. 46A *Time:* 10 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Setting up
2. Vertical milling
3. Face milling
4. Angle milling

Equipment:
Horizontal milling machine
Vise
$2\frac{1}{2}$" shell end mill
Dial indicator
Solid square
Vernier calipers
1" micrometer
Vertical milling head
File
$\frac{3}{16}$" dia. ball-end mill
Parallels

Materials:
Cast iron angle plate
$\frac{3}{4}$" x $2\frac{1}{2}$" x $2\frac{1}{2}$" x $3\frac{1}{4}$"

Selected references:
Anderson & Tatro. *Shop theory*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	TECHNIQUES AND RELATED INFO.
Note: The job described below (No. 1A) provides for producing workpieces measured conventionally (that is, in inches). Another sheet describes Job 1B which provides for producing essentially the same piece (precision angle plate) in metric dimensions (that is, millimeters). In both jobs angles are measured in degrees and screw threads and hole diameters are also in conventional measurements.	
1. Select stock and deburr.	
2. Set up a milling machine vise with the jaws parallel to the spindle.	2. Set the vise in the T-slot nearest the column and indicate.
3. Set up the $2\frac{1}{2}$" shell end mill.	3. Be sure that the locking screw is tight.
4. Set up the workpiece in the vise and mill surface G to clean up.	4. Surface A should be against the solid jaw and surface C down.
5. Take piece out of the vise and remove all burrs and sharp edges.	5. Clean the vise.
6. Set up the workpiece in the vise and mill surface A to clean up.	6. Put surface G against the solid jaw and surface B down.
7. Remove from the vise and take off burrs and sharp edges.	7. Clean the vise.
8. Set up workpiece in the vise and mill surface C to clean up.	8. Put surface G against the solid jaw and A down.
9. Remove from the vise and take off burrs and sharp edges.	9. Clean the vise.

PROCEDURE	TECHNIQUES AND RELATED INFO.
10. Set up the workpiece in the vise and mill surface B to 2.020".	10. Put surface A against the solid jaw and surface G down. The .020" oversize is left for grinding. Use vernier calipers for sizing.
11. Remove from vise and take off all burrs and sharp edges.	11. Clean the vise.
12. Mill surface H to 3.020".	12. Put surface A against the solid jaw with surface B down. .020" is left for grinding.
13. Remove from vise and take off all burrs and sharp edges.	13. Clean the vise.
14. Set up the workpiece and mill surface D to 2.020".	14. Keep H against the solid jaw and surface B down.
15. Remove from vise and take off all burrs and sharp edges.	15. Clean the vise.
16. Remove the shell end mill and set up the vertical milling head.	16. Clean the spindle hole and the vertical head drive surfaces.
17. Set up a $2\frac{1}{2}$" shell end mill in the vertical milling head.	17. Be sure the end mill locking screw is tight.
18. Set up the workpiece in the vise and mill surface F to .520".	18. Put surface G against solid jaw and surface B down. The .020" is left for grinding. Use suitable parallels. CAUTION: Do not climb mill.
19. Remove from vise and take off all burrs and sharp edges.	19. Clean the vise.
20. Set up the workpiece and mill surface E to .520".	20. Keep surface G against solid jaw and surface A down. The .020" is left for grinding. CAUTION: Do not climb mill.
21. Remove from vise and take off all burrs and sharp edges.	21. Clean the vise.
22. Remove shell end mill and set up $\frac{3}{16}$" dia. ball-end mill.	22. Replace shell mill arbor with suitable end mill adapter in spindle.
23. Set up vertical milling head at 45° angle.	23. Use degree graduations on head for setup. Be sure to retighten head after setting up.
24. Set up workpiece and mill undercut relief (for grinding).	24. Keep surface A against solid jaw and surface B down. Use suitable parallels. Pick up corner surfaces and before milling adjust depth to .115" for surfaces E and F. Use coolant.
25. Remove all burrs and sharp edges.	25. Clean all tools and machine. Return all tools to proper places.
26. Submit for inspection and grade.	

Unit No. *Operator's Job Title:* Milling Machine Operator

Project XII *Project Name:* Precision Angle Plate

Job No. 1B *Job Name:* Precision Angle Plate (millimeters) *D.O.T. No.* 605.380

Drawing No. 46B *Time:* 10 Hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Setting up
2. Vertical milling
3. Face milling
4. Angle milling

Equipment:
Horizontal milling machine
Vise
$2\frac{1}{2}$" shell end mill
$\frac{3}{16}$" dia. ball-end mill
Parallels
Solid square
15 cm. metric scale
Metric micrometer, 0-25 mm.
Vertical milling head
File

Materials:
Cast iron angle plate
19mm. x 64mm. x 64mm. x 83mm.

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	TECHNIQUES AND RELATED INFO.
NOTE: The job described below (No. 1B) will produce a workpiece essentially the same as the one produced in Job 1A. In Job 1B, however, the piece has been designed in metric dimensions except for the angle and the milled relief slot in the corner. In both jobs the angle is given in degrees and the milled slot in inches. The slot is given in inches because a milling cutter in conventional dimensions in easily available, but there is a question as to whether such a cutter would be available in school shops in metric dimensions.	
1. Select stock and deburr.	
2. Set up a milling machine vise with the jaws parallel to the spindle.	2. Set the vise in the T-slot nearest the column and indicate.
3. Set up the $2\frac{1}{2}$" shell end mill.	3. Be sure that the locking screw is tight.
4. Set up the workpiece in the vise and mill surface G to clean up.	4. Surface A should be against the solid jaw and surface C down.
5. Take piece out of the vise and remove all burrs and sharp edges.	5. Clean the vise.
6. Set up the workpiece in the vise and mill surface A to clean up.	6. Put surface G against the solid jaw and surface B down.
7. Remove from vise and take off all burrs and sharp edges.	7. Clean the vise.
8. Set up workpiece in the vise and mill surface C to clean up.	8. Put surface G against the solid jaw and A down.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
9. Remove from vise and take off all burrs and edges.	9. Clean the vise.
10. Set up the workpiece in the vise and mill surface B to 51.5 mm.	10. Put surface A against the solid jaw and surface G down. 0.5 mm. oversize is left for grinding. Use metric scale for sizing.
11. Remove from vise and take off all burrs and sharp edges.	11. Clean the vise.
12. Mill surface H to 77.5 mm.	12. Put surface A against the solid jaw with surface B down. The 0.5 mm. is left for grinding.
13. Remove piece from vise and take off all burrs and sharp edges.	13. Clean the vise.
14. Set up the workpiece and mill surface D to 51.5 mm.	14. Keep surface H against the solid jaw and surface B down.
15. Remove from vise and take off all burrs and sharp edges.	15. Clean the vise.
16. Remove the shell end mill and set up the vertical milling head.	16. Clean the spindle hole and the vertical head drive surfaces.
17. Set up the $2\frac{1}{2}$" shell end mill in the vertical milling head.	17. Be sure the end mill locking screw is tight.
18. Set up the workpiece in the vise and mill surface F to 13.5 mm.	18. Put surface G against solid jaw and surface B down. The 0.5 mm. is left for grinding. CAUTION: Do not climb mill.
19. Remove from vise and take off all burrs and sharp edges.	19. Clean the vise.
20. Set up the workpiece and mill surface E to 13.5 mm.	20. Keep surface G against solid jaw and surface A down. The 0.5 mm. is left for grinding.
21. Remove from vise and take off all burrs and sharp edges.	21. Clean the vise.
22. Remove shell end mill and set up $\frac{3}{16}$" dia. ball-end mill.	22. Replace shell mill arbor with suitable end mill adapter in spindle.
23. Set up vertical milling head at 45° angle.	23. Use degree graduations on head for setup. Be sure to retighten head after setup.
24. Set up workpiece and mill undercut relief (for grinding).	24. Keep surface A against solid jaw and surface B down. Use suitable parallels. Pick up corner surfaces and before milling adjust depth to .115" for surfaces E and F. Use coolant.
25. Remove all burrs and sharp edges.	25. Clean all tools and machine. Return all tools to proper places.
26. Submit for inspection and grade.	

Unit No. *Operator's Job Title:* Milling Machine Operator

Project XIII *Project Name:* 3-Inch Sine Plate

Job No. 1 *Job Name:* Plate *D.O.T. No.* 605.380

Drawing No. 63 *Time:* 12 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Plain milling
2. Angular milling
3. T-slot milling

Equipment:
- Horizontal milling machine
- Vertical milling machine
- Milling machine vise
- Parallels
- Solid square
- Vernier height gage
- Vernier protractor
- Micrometer
- $\frac{1}{4}$" end mill
- T-slot cutter
- Indicator
- $\frac{3}{8}$" side milling cutter

Materials:
1 piece CRS SAE 1020,
1" x 3" x 4$\frac{1}{2}$"

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select stock and deburr.	
2. Set up a plain milling cutter and a vise.	2. Set cutter overarm support as close to the column as possible.
3. Clamp the workpiece in the vise and machine one end clean and square.	3. Use a solid square to square the work in the vise and to check the squareness.
4. Reverse the workpiece and machine length to 4.280".	4. This will allow .030" for surface grinding after heat treating.
5. Remove from vise and deburr.	5. Clean the vise.
6. Set up a $\frac{3}{8}$" wide side milling cutter.	
7. Clamp the workpiece in the vise.	7. Use suitable parallels. Indicate the solid jaw parallel to the machine spindle.
8. Mill surfaces I and J.	8. Leave .030" for grinding on surface I.
9. Mill surfaces G and K.	9. The distance between surfaces J and K should remain at 2.999".

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
10. Tilt the workpiece to a 15° angle in the vise.	10. Use a vernier protractor.
11. Mill the 15° angle to blend with surface G.	11. Use a plain milling cutter.
12. Set up a vise on a vertical milling machine.	12. Indicate the solid jaw parallel to the T-slots.
13. Set up an end mill.	13. Use a $\frac{9}{32}$" two-lipped end mill.
14. Mill the $\frac{9}{32}$" slot to a depth of $\frac{31}{64}$".	14. Use cutting oil and do not overload the end mill.
15. Set up a T-slot cutter and complete the T-slot.	15. Keep the chips cleared out of the slot with a brush.
16. Submit for inspection and grade.	16. Clean the machine and tools. Return all tools to proper places.

Unit No. *Operator's Job Title:* Milling Machine Operator

Project XIII *Project Name:* 3" Sine Plate

Job No. 2 *Job Name:* End Stop *D.O.T. No.* 605.380

Drawing Nos. 63, 64 *Time:* 4 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. End milling
2. Drilling
3. Setting up

Equipment:
Vertical milling machine
Vise
$\frac{1}{2}$" end mill
Solid square
Vernier calipers
Parallels
Edge finder
$\frac{17}{64}$" drill
Countersink

Materials:
1 piece CRS SAE 1020,
$\frac{3}{16}$" x 1" x $3\frac{1}{4}$"

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select stock and deburr.	
2. Set up the head of the vertical milling machine with a $\frac{1}{2}$" end mill.	
3. Tighten the workpiece in the vise and mill one end square and to clean up.	3. Lay work flat in vise. Extend $\frac{1}{2}$" over end of vise.
4. Reverse the workpiece in the vise and mill the length to 2.980".	4. Leave .010" for grinding.
5. Set up an edge finder in the spindle.	
6. Position the piece for drilling the first hole by locating its center .375" from one side of the piece and .255" from the end.	
7. Drill the hole $\frac{17}{64}$".	
8. Countersink the hole $\frac{1}{32}$".	
9. Move table 2.470" and repeat steps 7 and 8.	
10. Remove piece from the vise and deburr.	
11. Submit for inspection and grade.	11. Clean all tools and machine. Return all tools to their proper locations.

Unit No. *Operator's Job Title:* Milling Machine Operator

Project XIV *Project Name:* Planer Gage

Job No. 1 *Job Name:* Base *D.O.T. No.* 605.380

Drawing Nos. 65, 66 *Time:* 12 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Setting up
2. End milling
3. Angular milling
4. T-slot milling
5. Face milling

Equipment:
Vertical milling machine
Horizontal milling machine
Swivel vise
Dial indicator
Angle plate
T-bolts, straps, and raise blocks
Parallel clamps
$\frac{1}{4}$" end mill
$1\frac{1}{4}$" end mill
3" shell end mill
T-slot cutter
Parallels
1" micrometer
Vernier calipers
Vernier protractor
45° single-angle cutter
Precision T-slot blocks

Materials:
1 piece SAE 2340,
$1\frac{1}{4}$" x 3" x $5\frac{3}{4}$"

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select stock and deburr.	
2. Set up a swivel vise on a vertical milling machine.	2. Set vise jaws parallel with the table T-slots by using an indicator.
3. Set up a 3" shell end mill.	
4. Set up to machine surface H.	4. Place workpiece flat on parallels in the vise, with surface G down.
5. Machine surface H.	5. Remove approximately $\frac{1}{8}$" of material.
6. Remove workpiece from the vise and deburr.	
7. Set up to machine surface A.	7. Place surface H against the solid jaw and clamp the piece securely.
8. Machine surface A.	8. Remove enough material to clean up.

PROCEDURE	TECHNIQUES AND RELATED INFO.
9. Set up to machine surface G.	9. Place the workpiece in the vise with surface A against the solid jaw and surface H down. Clamp the piece securely.
10. Machine surface G.	10. Machine to a thickness of 1.030". This leaves .030" for grinding.
11. Set up to machine the side opposite surface A (which will become surface C).	11. The side opposite A at this time is parallel to it, since it has not yet been machined to the angle shown on the drawing. Place the workpiece in the vise with surface G against the solid jaw and surface A down.
12. Machine the side opposite A.	12. Remove enough material to clean up.
13. Set up to machine surface B.	13. Leave the workpiece in the vise as in step 12 but protruding from the vise about $\frac{1}{2}$".
14. Machine surface B.	14. Use the side of the end mill to clean up the surface.
15. Set up to machine surface J.	15. Leave the workpiece in the vise as in step 14 but slide it so it protrudes out of the opposite side of the vise about $\frac{1}{2}$".
16. Machine surface J.	16. Machine to 5.530". This leaves .030" for grinding.
17. Remove workpiece from the vise and deburr.	17. Now send the workpiece to the bench to have lines C, D, E, and F laid out. Then send it to the drill and bandsaw to remove the material inside of lines D, E, and F.
18. Set up to machine surfaces D and E.	18. Place the work on narrow parallels flat in the vise, with surface A against the solid jaw. Use a $\frac{1}{4}$" end mill to round the corners.
19. Machine surfaces D and E.	
20. Machine surface A.	20. Swing the vise 19° to aline surface A with the direction of table movement.
21. Remove workpiece from vise.	21. Now send the workpiece to the bandsaw to remove the triangular portion outside of line C.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
22. Set up to machine surface C.	22. Set up the angle plate against precision T-slot blocks. Clamp the workpiece to the angle plate with line C parallel to and at least $\frac{1}{2}$" above the top of the angle plate. Double check the setup by placing a vernier protractor, set at 19°, between side B and the base of the table. Use a $1\frac{1}{4}$" end mill.
23. Mill surface C.	23. Make surface B $2\frac{3}{4}$" long plus $\frac{1}{32}$" for grinding.
24. Mill the $\frac{9}{32}$" slot.	24. Use a $\frac{1}{4}$" end mill. Mill the slot $\frac{31}{64}$" deep and center it. Check the width with vernier calipers.
25. Mill the T-slot.	25. Replace the $\frac{1}{4}$" end mill with an appropriate T-slot cutter. The bottom of the T-slot is to be $\frac{1}{2}$" from surface C, thus allowing $\frac{1}{64}$" grinding stock on surface C.
26. Remove the angle plate from the mill with the workpiece still attached.	26. Clean the machine, since the remaining operations will be done on a horizontal mill.
27. Set up the horizontal mill to machine the 45° angles.	27. Mount a single-angle 45° cutter on the horizontal mill. Secure the angle plate against the precision T-slot blocks.
28. Mill one of the 45° angles.	28. Remove enough material to leave a width of $\frac{3}{32}$" at the top.
29. Mill the other 45° angle.	29. To mill this surface turn the cutter around on the arbor. Take off enough material to obtain a $\frac{3}{32}$" flat at the top.
30. Remove workpiece from the machine and deburr it.	
31. Submit for inspection and grade.	

Unit No. *Operator's Job Title:* Milling Machine Operator

Project XIV *Project Name:* Planer Gage

Job No. 2 *Job Name:* Slide *D.O.T. No.* 605.380

Drawing Nos. 65, 67 *Time:* 12 hours

Performance Objectives:

Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:

1. Setting up
2. Plain milling
3. End milling
4. Slotting
5. Angular milling
6. Drilling
7. Tapping

Equipment:

Vertical milling machine
Horizontal milling machine
Shell end mill
$\frac{3}{8}$" end mill
Swivel vise
Universal vertical head
No. 29 drill
Center drill
Drill chuck
8-32 UNC tap
$\frac{1}{4}$" end mill
$\frac{17}{64}$" drill
Parallels
Dial indicator
$\frac{3}{32}$" slitting saw
Dial indicator
Solid square
Vernier protractor
Edge finder
Vernier calipers

Materials:

1 piece SAE 2340, $1\frac{1}{4}$" x $1\frac{1}{2}$" x $3\frac{3}{8}$"

Selected references:

Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select stock and deburr.	
2. Set up a swivel vise on a horizontal milling machine.	2. Clean all mating parts. Set the fixed jaw parallel to the T-slots.
3. Set up a plain helical milling cutter.	3. Clean the arbor and all collars and cutter surfaces.
4. Clamp the workpiece in the vise and mill surface T.	4. Set side A against the fixed jaw and surface H down on a pair of suitable parallels. Remove $\frac{1}{8}$" of material.
5. Clamp the workpiece in the vise and mill surface B.	5. Set side T against the fixed jaw and side A down on the parallels.
6. Clamp the workpiece in the vise and mill surface H to 1.020".	6. Keep side B against the fixed jaw and T down on the parallels. Leave the extra .020" for finish grinding.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
7. Clamp the workpiece in the vise and mill surface A to 1.270".	7. Keep side T against the fixed jaw and side B down on the parallels.
8. Set up a universal vertical milling head.	8. Set the vertical head square with the machine table, using a dial indicator.
9. Swivel the vise 90°.	9. Indicate the fixed jaw of the vise.
10. Set up a $2\frac{3}{4}$" shell end mill and mill end G to clean up.	10. Aline the workpiece using a solid square. Set the square on top of the fixed jaws.
11. Set up the workpiece and mill end F to 2.270".	11. Aline workpiece as above. .020" is left for finish grinding.
12. Set up and mill surfaces D and E.	12. Mill conventionally toward the fixed jaw. Leave .020" on surface E for finish grinding.
13. Set up and mill the $\frac{3}{32}$" x $\frac{3}{32}$" slot at 45° angle.	13. Set the vertical milling head over to 45° angle.
14. Reset the vertical head and locate and drill the No. 29 hole for the 8-32 UNC thread in surfaces B and E.	14. Follow local shop procedure.
15. Reset to locate and drill for the 8-32 UNC thread in surface D.	15. Use a solid square to aline the workpiece with the top of the vise jaws.
16. Locate and drill the three $\frac{1}{8}$" radius corner holes for the hollow area.	16. Lay the workpiece on its side with side B against the fixed jaw.
17. Set up a $\frac{1}{4}$" end mill and mill the inner surface running parallel to surface B.	17. Set table stops to avoid overrun of the cutter.
18. Mill the inner surface parallel to surface D.	18. Set table stops to avoid overrun of the cutter.
19. Swivel the vise to 19° and mill the inner surface running parallel to surface C.	
20. Swivel the vise.	20. Indicate the fixed jaw parallel to the T-slots, using a dial indicator.
21. Mill surface C to $1\frac{5}{8}$" length.	21. Use a vernier protractor to set workpiece to 19° angle. Leave .020" for finish grinding.
22. Mill the flat at the bottom of the angular slot to size.	22. Use a $\frac{3}{8}$" dia. end mill. Keep slot central to width of workpiece and parallel to surface C.
23. Mill the 45° slanted walls to size.	23. Tilt the universal vertical head to 45° and mill one wall with the end teeth of

PROCEDURE	TECHNIQUES AND RELATED INFO.
	the cutter and the other wall with its periphery. CAUTION: Keep the slot centered in the width of the workpiece. Also, be sure to leave stock for finish grinding.
24. Locate the $\frac{17}{64}$" hole in surface C.	24. Follow local shop procedure.
25. Center drill and drill the $\frac{17}{64}$" hole.	
26. Remove from vise, deburr, and submit for inspection.	26. Clean tools and machines. Return all tools to proper locations.

Unit No. *Operator's Job Title:* Milling Machine Operator

Project XV *Project Name:* Micrometer Boring Head

Job No. 1 *Job Name:* Dial *D.O.T. No.* 605.380

Drawing Nos. 22, 23 *Time:* 7 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawings in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Setting up
2. Angular cutting
3. Index graduating

Equipment:
Horizontal milling machine
Tilt dividing head
$\frac{1}{2}$" collet
60° angle cutter
Height gage

Materials:
1 piece CRS SAE 1020,
1" dia. x $\frac{3}{4}$" long from
the engine lathe operation

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select workpiece from engine lathe operation.	1. Check all dimensions before proceeding with milling machine operations.
2. Set up a tilt dividing head at 45°.	2. Hold workpiece in a $\frac{1}{2}$" collet or in a threaded split bushing and a 4-jaw chuck.
3. Mount a 60° angle cutter on an arbor or use a 60° tool bit held in a fly cutter holder.	3. Cutter can remain stationary and locked in position and be used as a planer tool.
4. Set dividing head to index 100 divisions.	4. Use the formula $\frac{40}{\text{No. of divisions}}$ to determine plate hole number and turns needed.
5. Aline the workpiece with the cutter.	5. Lay out the center of workpiece with a height gage and make 20 turns of the index crank so the layout line is now in a vertical position.

PROCEDURE	TECHNIQUES AND RELATED INFO.
6. Touch off the cutter on the work and raise the machine table .003".	
7. Cut one line.	7. Index the calculated divisions of the index crank.
8. Repeat step 7 until 100 divisions are completed.	
9. Remove all burrs and submit the piece for inspection and grade.	9. Clean all tools and the machine. Return all tools to proper places.

Unit No. *Operator's Job Title:* Milling Machine Operator

Project XV *Project Name:* Micrometer Boring Head

Job No. 2 *Job Name:* Plate *D.O.T. No.* 605.380

Drawing Nos. 22, 22.1 *Time:* $1\frac{1}{2}$ hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawings in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Plain milling
2. Setting up

Equipment:
Horizontal milling machine
Milling vise
Plain milling cutter
2 to 3" micrometer
Solid square

Materials:
1 piece CRS SAE 1020,
$\frac{1}{2}$" x 2" x $2\frac{1}{4}$"

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select stock and deburr.	
2. Set up plain milling cutter and vise.	2. Calculate and set speeds and feeds.
3. Set up workpiece in the vise and mill one end square and to clean up.	3. Keep sawed end up. Use a solid square against a finished side of the workpiece.
4. Deburr and check for squareness.	4. Use a solid square.
5. Mill the opposite end to $2\frac{1}{64}$" length, square and parallel.	5. The extra $\frac{1}{64}$" is left for grinding.
6. Deburr and submit for inspection and grade.	6. Clean all tools and machine. Return all tools to proper places.
7. Send to Drill Press for drilling, tapping, and reaming of holes.	
8. Send to Bench for alinement and assembly into the complete boring head.	

Unit No. *Operator's Job Title:* Milling Machine Operator

Project XV *Project Name:* Micrometer Boring Head

Job No. 3 *Job Name:* Dovetail Blocks *D.O.T. No.* 605.380

Drawing Nos. 22, 22.2 *Time:* 7 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawings in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Setting up
2. Angular milling
3. Plain milling

Equipment:
Vertical milling machine
Indicator
Vernier protractor
Vise
$1\frac{1}{4}$" end mill
Parallels
Square

Materials:
1 piece CRS SAE 1020, or phosphor bronze SAE 64, $\frac{3}{4}$" x $1\frac{1}{4}$" x $4\frac{5}{8}$"

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select stock and deburr.	
2. Set up an end mill and a swivel vise on a vertical milling machine.	2. Use a $1\frac{1}{4}$" dia. cutter. CAUTION: Use a shop cloth to handle cutter. Indicate vise parallel to the T-slots.
3. Clamp the workpiece in the vise and mill surface C to clean up.	3. Put side A against the solid jaw and side D down. Use suitable parallels.
4. Remove workpiece from vise and take off all burrs.	4. Clean the vise and parallels.
5. Clamp the workpiece in the vise and mill surface A.	5. Put side C against the solid jaw and side B down on the parallels. Remove $\frac{1}{8}$" of material.
6. Remove workpiece from the vise and take off all burrs.	6. Clean the vise and parallels. Check for squareness with a solid square.
7. Clamp the workpiece in the vise and mill surface B to 1.020".	7. Put side C against the solid jaw and side A down on the parallels. The .020" extra is left for surface grinding.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
8. Tilt the vertical head 8°.	
9. Clamp the workpiece in the vise and mill the 8° angle on surface D to .708".	9. Side A against solid jaw and side C down on the parallels.
10. Set milling head to vertical position.	10. Square the head to the milling machine table using a dial indicator.
11. Remove workpiece from the vise and deburr.	11. Clean the vise and the parallels.
12. Clamp in vise and mill end E square and to clean up.	12. Lock the longitudinal slide and use the crossfeed slide to feed the work.
13. Remove piece from vise and deburr.	13. Clean the vise and parallels.
14. Clamp workpiece in vise and mill end F square and to $4\frac{1}{2}$".	14. Lock the longitudinal slide and use the crossfeed slide to feed the work.
15. Submit for inspection and grade.	15. Clean all tools and machine. Return all tools to proper places.
16. Send to Bench for layout of: 4 holes of $\frac{11}{64}$" diameter, and 2 holes of $\frac{21}{64}$" diameter.	
17. Send to Drill Press for: drilling and reaming of the four $\frac{11}{64}$" holes, and drilling and counterboring of the two $\frac{21}{64}$" holes.	

Unit No. *Operator's Job Title:* Milling Machine Operator

Project XV *Project Name:* Micrometer Boring Head

Job No. 4 *Job Name:* Dovetail Slide *D.O.T. No.* 605.380

Drawing Nos. 22, 24 *Time:* 4 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawings in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Setting up
2. Fly cutting
3. End milling
4. Angular milling

Equipment:
Vertical milling machine
Swivel vise
Tilt vise
$\frac{5}{16}$" end mill
Fly cutter
Dial Indicator
Vernier calipers
Vernier protractor
Parallels
Edge finder

Materials:
1 piece CRS.SAE 1020,
1" x 1" x $1\frac{3}{8}$"
from engine lathe operation

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select material from engine lathe operation.	1. Check workpiece dimensions before proceeding with milling operations.
2. Set up a vise.	2. Indicate solid jaw parallel to T-slots.
3. Set up a $\frac{5}{16}$" end mill.	
4. Clamp workpiece in vise and mill $\frac{5}{16}$" slot to finished length.	4. Set piece on suitable parallels. Use an edge finder to aline machine spindle with the center of the workpiece.
5. Mill slot until milling cutter breaks through threaded hole.	
6. Set up a tilt vise.	6. Indicate the solid jaw parallel to T-slots before tilting to an 8° angle.
7. Clamp the workpiece in the vise.	7. Use suitable parallels and clean all surfaces.
8. Set up a $1\frac{1}{2}$" fly cutter.	
9. Mill the 8° angle on one side of the workpiece.	9. Use a vernier protractor to check angle.

PROCEDURE	TECHNIQUES AND RELATED INFO.
10. Remove the piece from the vise.	10. Notice carefully which surface is against the solid jaw. Clean all surfaces of the workpiece and the vise.
11. Reset the workpiece in the vise to mill the opposite 8° angle.	11. Keep the same surface against the solid jaw as in the previous step.
12. Mill the 8° angle to $\frac{29}{32}$" width.	12. Keep $\frac{11}{32}$" hole centered by measuring with a vernier caliper.
13. Submit for inspection and grade.	13. Clean all tools and machine. Return all tools to proper locations.

Unit No. *Operator's Job Title:* Milling Machine Operator

Project XVI *Project Name:* Grinding Vise

Job No. 1 *Job Name:* Lead Screw Nut *D.O.T. No.* 605.380

Drawing Nos. 36, 37 *Time:* 3 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawings in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. End milling
2. Left-hand tapping
3. Drilling

Equipment:
Vertical milling machine
Milling machine vise
End mill
Letter "I" drill
Center drill
$\frac{5}{16}$ - 24 L.H. tap
Countersink
1" micrometer
Solid square
Drill chuck

Materials:
1 piece CRS SAE 1020, $1\frac{1}{4}$" dia. x 1.435" long, machined on the lathe

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select workpiece from lathe operation.	1. Inspect dimensions of workpiece before continuing with milling operations.
2. Mount a milling vise on a vertical milling machine.	2. Indicate vise with solid jaw parallel to T-slot.
3. Set workpiece in a V-block and clamp in vise.	3. Have the $1\frac{1}{4}$" dia. up.
4. Mill a flat on one side.	4. Calculate the amount of material to remove to keep flats central.
5. Mill opposite flat to .740".	5. Use a 1" micrometer to measure.
6. Remove piece from vise.	6. Take off all burrs and clean the vise.
7. Set the workpiece in the vise, clamping on the 1.435" length.	7. Square the flat surface using a solid square from the base of the vise. Use a soft piece of material with opposite sides parallel under the .562" dia. to prevent the piece from sliding in the vise.

PROCEDURE	TECHNIQUES AND RELATED INFO.
8. Set up a drill chuck.	
9. Center the .560" dia. and determine location for the letter "I" drilled hole.	
10. Center drill and drill the letter "I" hole through the .560" dia.	
11. Countersink and tap.	11. Use a $\frac{5}{16}$-24 L.H. tap. Start tap on tne machine.
12. Remove the work from the machine and submit for inspection and grade.	

Unit No. *Operator's Job Title:* Milling Machine Operator

Project XVI *Project Name:* Grinding Vise

Job No. 2 *Job Name:* Sliding Jaw *D.O.T. No.* 605.380

Drawing Nos. 36, 40 *Time:* 10 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawings in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Slab milling
2. Angular milling
3. Drilling
4. Counterboring
5. Setting up

Equipment:
Horizontal milling machine
Vertical milling machine
$\frac{5}{16}$" drill
Swivel vise
$\frac{7}{16}$" and $\frac{9}{16}$" counterbores
Center drill
90° double angle cutter
Edge finder
$\frac{3}{4}$" x 4" side milling cutter
1 to 2" micrometer
Slab milling cutter
Square
Depth micrometer

Materials:
1 piece CRS SAE 1020,
$1\frac{1}{4}$" x $1\frac{1}{2}$" x 2"

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select stock and deburr.	
2. Set up a vise on a horizontal milling machine.	2. Indicate the solid jaw parallel to the T-slots.
3. Set up a slab milling cutter.	
4. Clamp the workpiece in the vise and mill both sides of the $1\frac{1}{4}$" thickness to 1.125".	4. Set the workpiece in the vise, using a solid square.
5. Place the piece in the vise with one of the machined surfaces against the solid jaw and the surface with the V-grooves up.	
6. Set up a 90° cutter.	6. Clean all sleeves, the cutter and the arbor.
7. Locate and mill the two 90° V-grooves .390" and .890" from the bottom of the workpiece.	7. Allow .010" for grinding.
8. Remove piece from vise and reposition it to mill bottom slot.	
9. Set up a $\frac{3}{4}$" x 4" side milling cutter.	

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
10. Mill the slot to 1.700" x .125".	10. Keep the slot centered in the piece.
11. Remove the workpiece from the machine.	11. Clean up the machine and put away the tools.
12. Set up a drill chuck on a vertical milling machine.	
13. Set up a vise and clamp the work in it to machine the hole.	13. Indicate the vise square in either direction.
14. Locate the center of the 1.966" x 1.480" bottom surface.	14. Use a milling machine wiggler or an edge finder.
15. Center drill and drill $\frac{5}{16}$" hole through 1.095" thickness.	15. Use cutting oil.
16. Counterbore .562" x .480" deep.	16. Counterbore .015" deeper to compensate for grinding.
17. Reverse piece and counterbore .437" x .330" deep.	17. Counterbore .015" deeper to compensate for grinding.
18. Remove piece from the vise and submit it for inspection and grade.	18. Clean the machine and tools. Put away all tools.

Unit No. *Operator's Job Title:* Milling Machine Operator

Project XVI *Project Name:* Grinding Vise

Job No. 3 *Job Name:* End Nut *D.O.T. No.* 605.380

Drawing Nos. 36, 38 *Time:* 1 hour

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawings in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Slotting
2. Slitting
3. Setting up

Equipment:
Horizontal milling machine
Index head
3-jaw chuck
$\frac{1}{16}$" slitting saw
6" scale

Materials:
1 piece drill rod
.490" dia. x .990"
machined on engine lathe

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select workpiece from lathe operation.	
2. Tighten workpiece in 3-jaw chuck with $\frac{1}{4}$" tapped hole end extending $\frac{1}{4}$" from the chuck.	2. Use index head in vertical position.
3. Mount $\frac{1}{16}$" slitting saw and center on .490" dia.	3. Use local shop procedure.
4. Mill slot to $\frac{1}{16}$" depth.	
5. Deburr and submit for inspection and grade.	

Unit No. *Operator's Job Title:* Milling Machine Operator

Project XVI *Project Name:* Grinding Vise

Job No. 4 *Job Name:* Base *D.O.T. No.* 605.380

Drawing Nos. 36, 39 *Time:* 18 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawings in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Face milling
2. Squaring
3. Drilling
4. Reaming
5. Counterboring
6. Plain milling
7. Slotting

Equipment:
- Horizontal milling machine
- Vertical milling machine
- Milling machine vise
- $\frac{5}{16}$" reamer
- Dial indicator
- $\frac{19}{64}$" drill
- Center drill
- $\frac{1}{2}$" end mill
- Telescopic gage
- $\frac{1}{4}$" x 4" plain milling cutter
- $2\frac{3}{4}$" shell end mill
- Drill chuck
- Wiggler
- $\frac{7}{32}$" x $\frac{5}{8}$" side milling cutters
- 1" micrometer
- 2" micrometer
- $\frac{7}{16}$" and $\frac{1}{2}$" counterbores
- 1" depth micrometer

Materials:
1 piece CRS SAE 1020, 2" x 2" x $4\frac{5}{8}$"

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select stock and deburr.	
2. Set up a swivel vise on a horizontal milling machine.	2. Indicate and aline the solid jaw parallel to the machine spindle.
3. Clamp the workpiece in the vise.	3. Extend the work $\frac{1}{2}$" beyond the end of the vise jaws.
4. Set up a shell end mill and mill one end clean and square.	4. Be sure that the cutting pressure is toward the solid jaw of the vise. Check with a solid square.
5. Reverse the workpiece and mill to 4.390".	5. Remove the burrs and clean the vise.
6. Remove the shell end mill and set up a drill chuck.	6. Clean the workpiece and the vise carefully.
7. Clamp the workpiece in the vise and aline.	7. Use a dial indicator and check the entire length of the work for parallelism. Adjust if necessary.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
8. Set up an edge finder and locate the center for the $\frac{5}{16}$" reamed hole, counterbored .437".	
9. Center drill, pilot drill and drill this hole $\frac{19}{64}$" x $1\frac{3}{4}$" deep.	
10. Ream $\frac{5}{16}$" hole and counterbore .437" x .325" deep.	10. Counterbore .015" deeper than dimension shown to allow for finish grinding.
11. Remove from the vise and reverse the workpiece and clamp.	11. Check the work for parallelism with a dial indicator. Adjust if necessary. Keep the same surface down in the vise.
12. Repeat operations 9 and 10 on $\frac{5}{16}$" hole with counterbore .500" x 1.000" deep.	12. Counterbore .015" deeper to 1.015" to allow for finish grinding.
13. Remove from vise and deburr.	13. Clean the vise and workpiece.
14. Swivel the vise 90° and remove the drill chuck.	14. Indicate the solid jaw parallel to the T-slots. Clean all tools and return them to their proper places.
15. Set up the workpiece and a $\frac{7}{32}$" x 4" side milling cutter.	15. Clean the spindle, arbor sleeves, etc.
16. Mill the .250" x .130" slot on one side of the workpiece.	16. Keep the base of the workpiece against the solid jaw of the vise. Mill .010" deeper, (to .140") to allow for finish grinding of outer surface of workpiece.
17. Remove from vise and deburr.	17. Clean the vise.
18. Mill the .250" slot on the opposite surface.	18. Repeat step 16.
19. Remove the $\frac{7}{32}$" cutter and mount a $\frac{5}{8}$" x 4" side milling cutter. Remove the workpiece from the vise and deburr.	
20. Mount the piece in the vise with bottom side up and position the cutter for the .750" x .125" slot.	20. Use the touchoff method to position the cutter on the workpiece center.
21. Mill the .750" slot to .740".	21. Mill .010" deeper (to .135") to allow for grinding outer surface.
22. Send to be sawed.	
23. Set up a vertical milling machine with a plain vise and a shell end mill.	23. Indicate the solid jaw of the vise parallel to the T-slots.
24. Mill the 1.000" thickness to 1.030" up to the solid jaw.	24. Leave .015" for finish grinding on this surface. Also leave excess material at the intersection as explained on the drawing.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
25. Mill the solid jaw .875" dimension to .905".	25. This will leave material for finish grinding.
26. Set up a drill chuck for one of the ½" holes at the ends of the .563" slot. Locate the drill over the hole.	26. Use a milling machine wiggler or an edge finder.
27. Center drill and drill ½" holes at the ends of the .563" slot.	27. Record the dial settings at the center points of the two holes, keeping in mind the direction of the backlash.
28. Set up a ½" end mill and mill the slot to finish sizes by conventional milling, not climb milling.	
29. Remove from vise and deburr.	29. Clean the machine and tools. Return all tools to their proper places.
30. Submit for inspection and grade.	

Unit No. *Operator's Job Title:* Milling Machine Operator

Project XVII *Project Name:* V-Block

Job No. 1 *Job Name:* V-Block *D.O.T. No.* 605.380

Drawing No. 47 *Time:* 30 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Face milling
2. Slot milling
3. Angular milling

Equipment:
- Vertical milling machine
- Horizontal milling machine
- Swivel vise
- $2\frac{3}{4}$" shell end mill
- Toolmaker's universal tilting vise
- $\frac{3}{16}$" drill
- Drill chuck
- $\frac{5}{16}$" drill
- Dial indicator
- $\frac{5}{32}$" x 4" mill-saw
- Parallels
- $\frac{3}{16}$" x 4" milling cutter
- $\frac{7}{16}$" x 4" side milling cutter
- Countersink
- Solid square
- Vernier protractor
- 6" calipers
- File
- $\frac{5}{8}$" x 4" side milling cutter
- Letter F drill

Materials:
1 piece CRS SAE 1020,
2" x 2" x $3\frac{3}{4}$"

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	TECHNIQUES AND RELATED INFO.
1. Select stock and deburr.	1. Check overall sizes before proceeding.
2. Set up a $2\frac{3}{4}$" shell end mill in vertical milling machine.	2. CAUTION: Use a cloth to hold the cutter.
3. Set up a swivel vise and indicate.	3. Clean all mating surfaces. Indicate the solid jaw parallel to the T-slots.
4. Clamp the work in the vise.	4. Use a suitable pair of parallels.
5. Mill surface A to clean up and deburr.	5. Surface E will be against the solid jaw of the vise.
6. Mill surface B to clean up.	6. Surface E will be against the solid jaw of the vise.
7. Remove from the vise and deburr.	7. Clean parallels and the vise.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
8. Clamp the workpiece in the vise and mill surface B to $1\frac{7}{8}$".	8. Clean vise and parallels. Keep side E against the solid jaw.
9. Remove from the vise and deburr.	9. Clean the vise and parallels.
10. Clamp workpiece in the vise and mill surface D to $1\frac{29}{32}$".	10. Place surface B against the solid jaw.
11. Remove from vise and check sizes and squareness.	11. Use a solid square. Be sure to remove burrs.
12. Clamp the workpiece in an upright position in the vise.	12. Use a solid square to aline work. Put side G down in the vise.
13. Mill end F clean and square.	
14. Remove from the vise.	14. Clean the vise and remove all burrs. Check for squareness.
15. Clamp the workpiece in the vise and mill end G to $3\frac{21}{32}$" length.	15. $\frac{1}{32}$" is left for surface grinding. Check for squareness.
16. Set up a drill chuck.	16. Clean the chuck and all mating surfaces before assembly.
17. Clamp workpiece in the vise with E against the solid jaw.	
18. Locate the two $\frac{5}{16}$" drilled holes in surface B and drill.	18. Use local shop procedure.
19. Locate and drill letter F hole for $\frac{5}{16}$" tapped hole in surface C.	19. Do not tap the hole.
20. Remove from vise.	20. Remove all burrs; clean the vise and parallels.
21. Clamp in vise with surface B against the solid jaw.	
22. Locate the two $\frac{5}{16}$-18 tapped holes in surface D and drill through with letter F drill.	
23. Locate the $\frac{3}{16}$" diameter corner relief hole and drill.	23. Clear chips from drill often and use lubricant.
24. Remove from vise and send to the band saw.	24. Clean the vise and remove all burrs.
25. Set up a shell end mill.	
26. Clamp the workpiece in vise and mill surfaces C and H at the same time to bring the $\frac{5}{16}$" dimension on surface G to $\frac{1}{2}$" and the $1\frac{5}{8}$" dimension on surface C to size.	26. Keep surface A down on the parallels and surface E against the solid jaw.
27. Set up a $\frac{5}{32}$" x 4" mill-saw on a horizontal milling machine.	27. Clean the arbor, sleeves, etc. before mounting the cutter.
28. Set up a swivel vise and indicate.	28. Indicate parallel to the T-slots. Clean all surfaces on the vise and the table.
29. Mill the relief slot to $\frac{37}{64}$" depth into surface E	

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
30. Remove from vise and swivel the vise 90°.	30. Clean the vise and remove burrs.
31. Set workpiece in upright position in vise and mill $\frac{5}{32}$" relief slot to $\frac{37}{64}$" depth into surface G.	31. Put surface F down and surface A against the solid jaw.
32. Remove piece from vise.	32. Clean the vise and remove all burrs.
33. Set up a $\frac{3}{16}$" x 4" side milling cutter.	33. Clean cutter, arbor, and sleeves.
~~34. Set up~~ workpiece and mill $\frac{3}{16}$" x $\frac{27}{64}$" deep in surface D of tongue.	34. Keep surface B against solid jaw and surface E on parallels.
35. Remove from vise and reset workpiece to mill same size slot on opposite surface (E) of tongue.	35. Have surface A against solid jaw and surface D on parallels.
36. Check measurement across slots.	36. Size should be $1\frac{1}{16}$".
37. Change milling cutter to $\frac{5}{8}$" x 4" side milling cutter.	37. Clean all mating surfaces.
38. Mill the $\frac{5}{8}$" surface $\frac{1}{4}$" deep, using same procedure as steps 34 and 35.	38. Mill $\frac{1}{64}$" deeper than $\frac{1}{4}$" to allow for surface grinding.
39. Mill surfaces D and E of the tongue to $1\frac{5}{16}$" dimension.	
40. Swivel vise 90° and mount a $\frac{3}{16}$" x 4" side milling cutter.	40. Indicate solid jaw parallel to the T-slots.
41. Mill the $\frac{3}{16}$" x $\frac{27}{64}$" slot in surfaces D and E. ($\frac{27}{64}$" depth allows grinding stock.)	41. Measurement across body should be $1\frac{1}{16}$".
42. Mount a $\frac{7}{16}$" x 4" side milling cutter.	42. Clean all mating surfaces.
43. Mill flat surfaces $\frac{7}{16}$" wide on surfaces D and E.	
44. Mill $\frac{7}{16}$" x $\frac{1}{4}$" slots on surfaces D and E.	44. Mill $\frac{1}{64}$" deeper than $\frac{1}{4}$" to allow for surface grinding.
45. Remove workpiece from machine.	45. Clean machine and put tools away. Remove all burrs.
46. Set up a shell end mill in a vertical milling machine.	
47. Set up a toolmaker's universal vise.	47. Indicate the vise jaws parallel to the T-slots.
48. Tilt vise to 45° angle from the vertical.	48. Use a vernier protractor to set. Check after clamping.
49. Mill surfaces K and J.	49. Keep surface E against the solid jaw and surface A on suitable parallels. Leave $\frac{1}{64}$" for grinding.
50. Remove piece from vise.	50. Remove burrs; clean vise and parallels.
51. Clamp workpiece in vise with end G up.	51. Keep surface E against solid jaw.

PROCEDURE	TECHNIQUES AND RELATED INFO.
52. Mill surfaces M and L.	52. Leave $\frac{1}{64}$" oversize for surface grinding.
53. Remove from vise, check all sizes, and submit for inspection and grade.	53. Clean up machine and tools and return all tools to proper places.
54. Send to heat treat for hardening and tempering.	

Unit No. *Operator's Job Title:* Milling Machine Operator

Project XVIII *Project Name:* Grinding Fixture For Thread Tool

Job No. 1 *Job Name:* Base *D.O.T. No.* 605.380

Drawing No. 54 *Time:* 20 hours

Performance Objectives:

Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:

1. Face milling
2. Drilling
3. Counterboring
4. Boring
5. Slotting
6. Angular milling
7. Setting up

Equipment:

Vertical milling machine
Swivel vise
$2\frac{3}{4}$" shell end mill
Dial indicator
$\frac{3}{16}$" and $\frac{1}{4}$" end mills
Edge finder
Boring head
Boring bar
$\frac{3}{4}$" plug gage
Vernier protractor
Toolmaker's universal vise

Materials:

1 piece CRS SAE 1020, $1\frac{1}{4}$" x $1\frac{3}{4}$" x $2\frac{1}{2}$"

Selected references:

Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select stock and deburr.	
2. Set up a vertical milling machine with a swivel vise.	2. Indicate the solid jaw parallel to the T-slots.
3. Set up a shell end mill.	3. Clean all mating surfaces and be sure the locking screw of the arbor is tight.
4. Machine the workpiece to make all angles square.	4. Leave all dimensions .030" oversize to allow for finish grinding.
5. Set up a drill chuck. Locate, drill, and counterbore the two $\frac{5}{16}$" holes with a $\frac{7}{16}$" counterbore.	5. Use an edge finder to locate the holes. Counterbore .015" deeper to allow for surface grinding.
6. Turn piece over end for end and counterbore $\frac{5}{16}$" dia. holes to $\frac{7}{16}$" x $\frac{5}{16}$" deep.	
7. Locate and drill a $\frac{5}{8}$" dia. hole for the $\frac{3}{4}$" dia. bore.	
8. Remove drill chuck and replace with a precision boring head and boring bar.	
9. Locate and bore the $\frac{3}{4}$" hole.	9. Use the $\frac{3}{4}$" plug gage to size the hole.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
10. Remove the boring head, set up a $\frac{3}{16}$" end mill and cut the $\frac{1}{4}$" x $\frac{1}{4}$" slot.	10. Mill the slot .005" deeper to allow for finish grinding. Make width of slot .015" undersize and in the center of the piece.
11. Turn the work over and mill the $\frac{5}{16}$" slot using a $\frac{1}{4}$" end mill.	11. Repeat step 10.
12. Remove end mill and set up a toolmaker's universal vise and a $2\frac{3}{4}$" shell end mill.	12. Indicate the solid jaw parallel to the T-slots
13. Set up the workpiece to mill surface A as follows: Place the workpiece in the toolmaker's vise with surface E against the solid jaw of the vise, and end G upward and to the operator's left so the $\frac{5}{16}$" slot makes a 30° angle with the table of the milling machine. Use a vernier protractor to set the angle. Tilt the vise 7° by lowering the side of the vise containing the $\frac{5}{16}$" slot.	
14. Mill surface A.	14. CAUTION: Do not mill past the edge representing the $\frac{3}{8}$" flat on end G. Leave extra material for grinding.
15. Set up to mill surface B by following step 13 except that end G is to be upward and to the operator's right.	
16. Mill surface B.	16. Maintain the $\frac{3}{8}$" flat plus stock for grinding.
17. Set up to mill surface C as follows: Place the workpiece in a toolmaker's vise with surface F against the solid jaw of the vise and end H upward and to the operator's right so the $\frac{1}{4}$" slot makes a 30° angle with the table of the machine. Use a vernier protractor to set the angle. Tilt the vise 9°30' by lowering the side of the vise containing the $\frac{1}{4}$" slot.	
18. Mill surface C.	18. CAUTION: Do not mill past the edge representing the $\frac{3}{8}$" flat on end G. Leave extra material for grinding.
19. Set up to mill surface D as follows: Place the workpiece in a toolmaker's vise with surface F against the solid jaw of the vise and end H upward and to the operator's left so the $\frac{1}{4}$" slot makes a 30° angle with the table of the milling machine. Use a vernier protractor to set the angle. Tilt the vise 9°30' by lowering the side of the vise containing the $\frac{5}{16}$" slot.	

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
20. Mill surface D.	20. CAUTION: Do not mill past the edge representing the $\frac{3}{8}$" flat on end G. Leave extra material for grinding.
21. Set up to mill 20° angle on end G.	21. Aline $\frac{1}{4}$" slot using a solid square, with surface E against solid jaw.
22. Mill end G.	22. Maintain $\frac{7}{16}$" width plus grinding stock.
23. Set up to mill 20° angle on end H.	23. Aline $\frac{1}{4}$" slot using a solid square, with surface F against solid jaw.
24. Mill end H.	24. Maintain $\frac{3}{8}$" width plus grinding stock.
25. Submit for inspection and grade.	25. Clean all tools and machine. Put all tools in proper places.

Unit No. *Operator's Job Title:* Milling Machine Operator

Project XIX *Project Name:* Helical Milling Cutter

Job No. 1 *Job Name:* Helical Milling Cutter *D.O.T. No.* 605.380

Drawing No. 71 *Time:* 16 hours

Performance Objectives:
Using only the equipment, materials, and operations listed here, the student will be able to produce the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job the student will be able to complete similar jobs with like specifications.

Operations:
1. Setting up
2. Helical milling

Equipment:
- Universal horizontal milling machine
- Universal dividing head and tailstock
- Change gears
- Dial indicator
- Drive dog
- Mandrel
- Fluting cutter
- Vernier height gage

Materials:
High-speed steel cutter blank from engine lathe or turret lathe operation

Selected references:
Anderson & Tatro. *Shop theory.*
Brown & Sharpe. *Practical treatise on milling and milling machines.*
Jones. *Machine shop training course.*

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select workpiece from lathe operation.	
2. Coat one end of blank with layout dye and press it on a mandrel.	2. Position the end with layout dye on the small end of the mandrel.
3. Set up the dividing head and the change gears.	3. Select change gears to develop a 2-to-1 simple gear train ratio with 2 idlers to obtain a left-hand helix. CAUTION: Adjust the dividing head for helical milling. Refer to the machine manual for the dividing head.
4. Mount the tailstock and set the mandrel between centers.	4. Position the tailstock for the proper distance between centers and bolt it to the table. Attach the drive dog to the mandrel. Check the parallelism of the workpiece with the surface of the milling machine table, using a dial indicator attached to the height gage.

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
5. Swivel the table to the 25° helix angle.	5. Move the zero reference line to the left for a left-hand helix. Adjust the cross-slide so the table will clear the column at this angle.
6. Swivel the table back to zero.	6. Return the table to zero for cutter alinement.
7. Mount a fluting cutter on the arbor with the 12° angle toward the column.	7. Locate the cutter over the center of the work as closely as possible by arranging the collars on the arbor.
8. Aline the cutter with the workpiece.	8. Use a square and a ruler to measure in from each side of the work to the sides of the cutter. Set the diameter of the cutter so it just touches the workpiece.
9. Lay out two radial lines on the end of the blank and the 10° angle line.	9. Set the height gage scriber on the center of the work and scribe a line. Index one tooth space and scribe another line on center. Use 4 turns of the index head for one tooth space. Return the first radial line to the horizontal position and then index counterclockwise 10° by rotating the handle $1\frac{1}{9}$ turns. Reset the scriber point to the radial line at the circumference of the blank and scribe a line. This will make a 10° angle with the radial line for alining the 12° side of the cutter.
10. Set the cutter to the layout line.	10. Rotate the index head to bring the 10° layout line past the vertical and parallel with the 12° cutting edge of the fluting cutter. Move the workpiece outward to bring it off center, using the cross-slide.

PROCEDURE	TECHNIQUES AND RELATED INFO.
	CAUTION: The vertical centerline of the cutter and the face of a tooth must be in line with the end of the workpiece to correctly aline the cutter with the layout line.
11. Swivel the table 25°, which is the helix angle on the workpiece.	11. Rotate the table clockwise to the 25° setting and clamp it tight.
12. Rough cut the flutes.	12. Set the depth of cut at approximately $\frac{5}{16}$" and start the cutter into the work. As soon as a full cut is made stop and back the cutter out to check alinement. Adjust if necessary. Cut first flute all the way through. Lower the table to clear the cutter and return to the starting point. Index 4 turns for the next flute. Raise the table to depth setting and cut the second flute.
13. Repeat steps 8 through 12 for the rest of the flutes.	
14. Finish cut the flutes.	14. Check the layout lines and the amount of land left at the finish depth. Allow for .030" grinding stock on outside diameter.
15. Replace fluting cutter with $\frac{3}{4}$" plain milling cutter. Mill 20° secondary clearance angle on all flutes.	15. Index the workpiece so the outer tooth edge is on the vertical centerline. Rotate clockwise 20° to mill the secondary clearance angle. Set depth of cut to leave a $\frac{1}{32}$" maximum land before grinding. CAUTION: Lower the table before returning to starting point for each cut.
16. Remove workpiece and deburr. Submit for inspection and grade.	16. Press out mandrel, clean machine, and return all tools and equipment to proper places.

Bibliography

GENERAL

Anderson, James & Tatro, Earl E. *Shop theory;* 5th ed. New York, N.Y. McGraw-Hill. 1968.

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Jones, Franklin D. *Machine shop training course;* 5th ed. Vol. II. New York, N.Y. Industrial Press. 1964.

McCarthy, Willard J. & Smith, Robert E. *Machine tool technology;* 3d ed. Bloomington, Ill. McKnight. 1968. (Order from Taplinger Publishing Co., 200 Park Ave., S., New York, N.Y. 10003.)

Porter, Harold W. and others. *Machine shop operations and setups;* 3d ed. Chicago, Ill. American Technical Society. 1967.

Walker, John R. *Machining fundamentals.* South Holland, Ill. Goodheart-Willcox Co. 1969.

METRICATION

The best references on metrication today, because many changes are taking place, are articles in magazines and newspapers. However, the following two books contain pertinent and valuable information:

Holt, Susan Fraker. *The United States and the Metric System.* Ninth District Exponent, Dec. 1972. Federal Reserve Bank of Minneapolis. Minneapolis, Minn. 55480. (A good source of information on the metrication problem in general. Available in modest quantities without charge.)

Beloit Tool Corporation. *U.S.A. Goes Metric.* Swani Publishing Co., Box 248, Roscoe, Ill. 61073. (Contains considerable information on the technical aspects of metrication related to metalworking.)

Many of the magazines and journals on vocational and technical education have articles on metrication from time to time. The April 1974 issue of *School Shop* is a special issue devoted completely to metrics. The issue as a whole is very valuable but we especially recommend the following articles in it:

"The cutting edge of metrication," by Albert B. Chalupsky and Jack J. Crawford. Page 50.

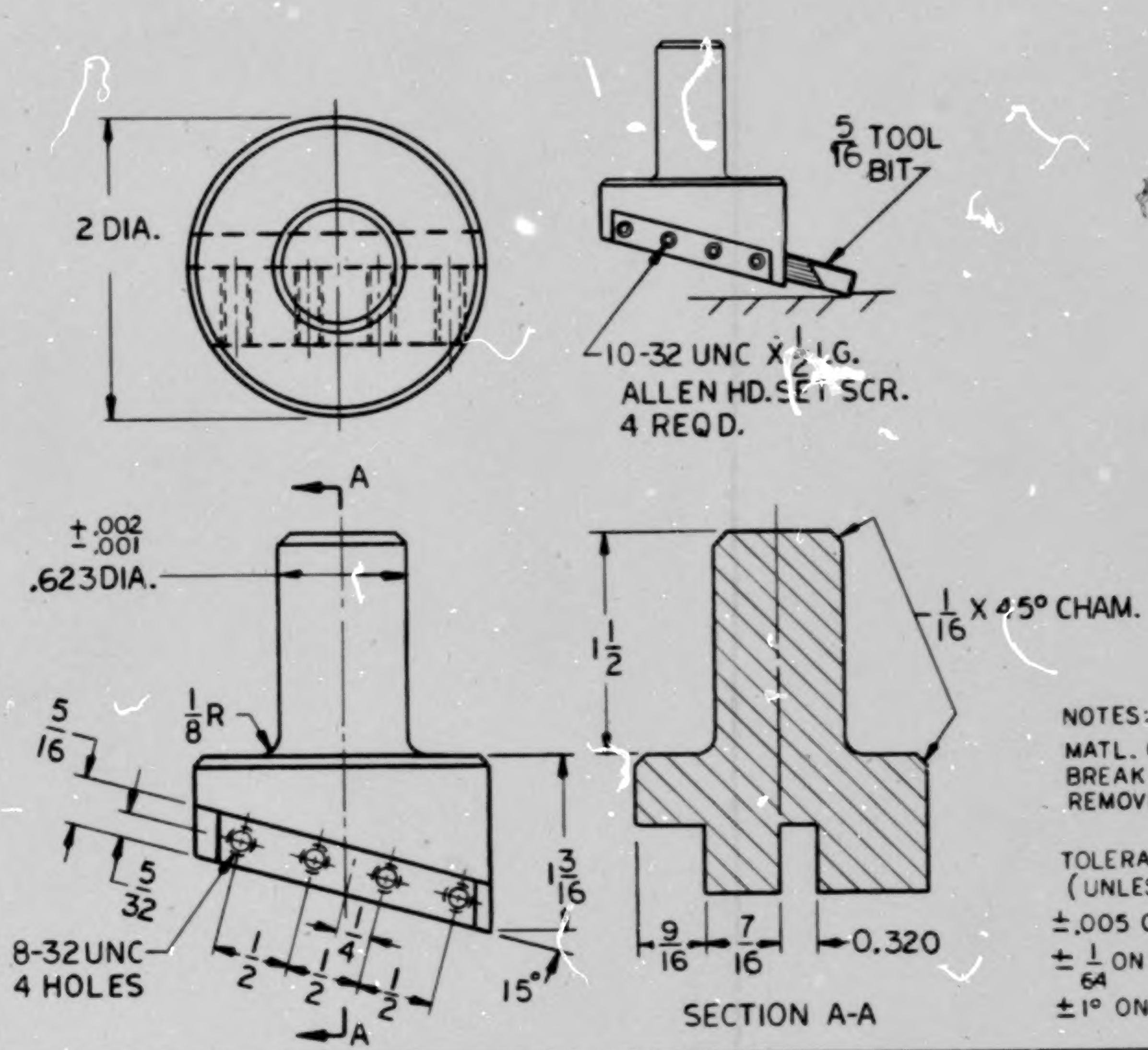
"Give 'em a centimetre and they'll take a kilometre," by James F. Snyder. Page 82.

"Metrication at Caterpillar: A talk with L.R. Strang." Page 62.

A new periodical on metrics, which began publication in 1973, is *Metric News*. It is published by Swani Publishing Co., P.O. Box 248, Roscoe Ill. 61073. Another valuable periodical is *Metric Association Newsletter* published quarterly by the Metric Association, 2004 Ash Street, Waukegan, Ill. 60085. This association also provides other publications and training aids and promotes the use of metric units in other ways.

Advertisements in the periodicals mentioned above and in others give information on tools, instruments, and training aids for metrics.

Drawings for Shop Projects

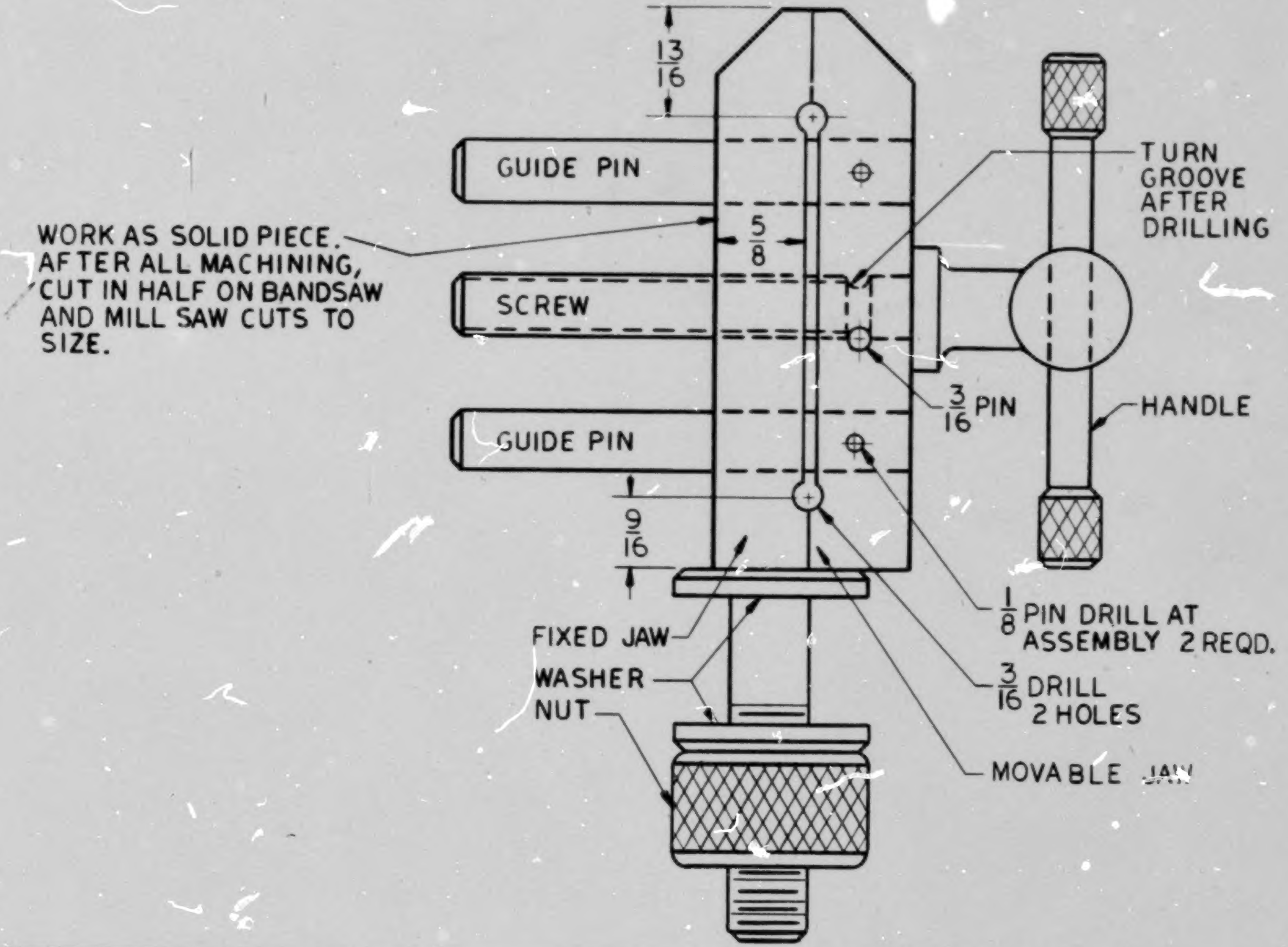

2 DIA.
5/16 TOOL BIT
10-32 UNC X 1/2 LG. ALLEN HD. SET SCR. 4 REQD.
A
±.002 −.001 .623DIA.
1/8R
5/16
5/32
8-32UNC 4 HOLES
1/2
1/2
1/4
1/2
A
1 3/16
15°
1 1/2
1/16 X 45° CHAM.
9/16
7/16
0.320

SECTION A-A

NOTES:
MATL. CRS
BREAK ALL SHARP EDGES
REMOVE ALL BURRS

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
±.005 ON DECIMAL DIMENSIONS
± $\frac{1}{64}$ ON FRACTIONAL DIMENSIONS
±1° ON ANGULAR DIMENSIONS

DRAWN BY: E.F.S.	FLY TOOL	
SCALE: ——	FACE CUTTER	DWG.NO. 8

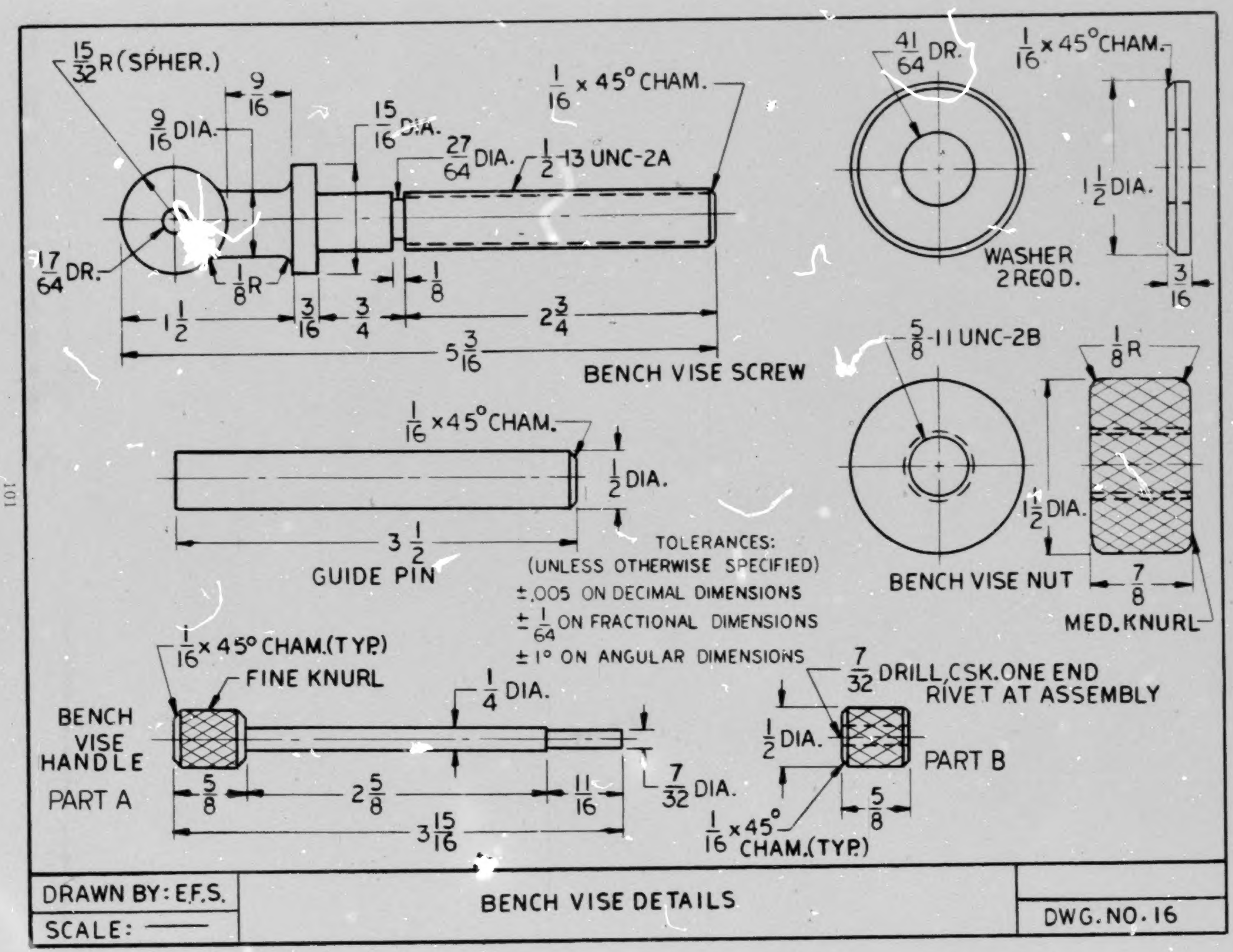

13/16
GUIDE PIN
WORK AS SOLID PIECE. AFTER ALL MACHINING, CUT IN HALF ON BANDSAW AND MILL SAW CUTS TO SIZE.
5/8
SCREW
GUIDE PIN
9/16
TURN GROOVE AFTER DRILLING
3/16 PIN
HANDLE
1/8 PIN DRILL AT ASSEMBLY 2 REQD.
3/16 DRILL 2 HOLES
MOVABLE JAW
FIXED JAW
WASHER
NUT

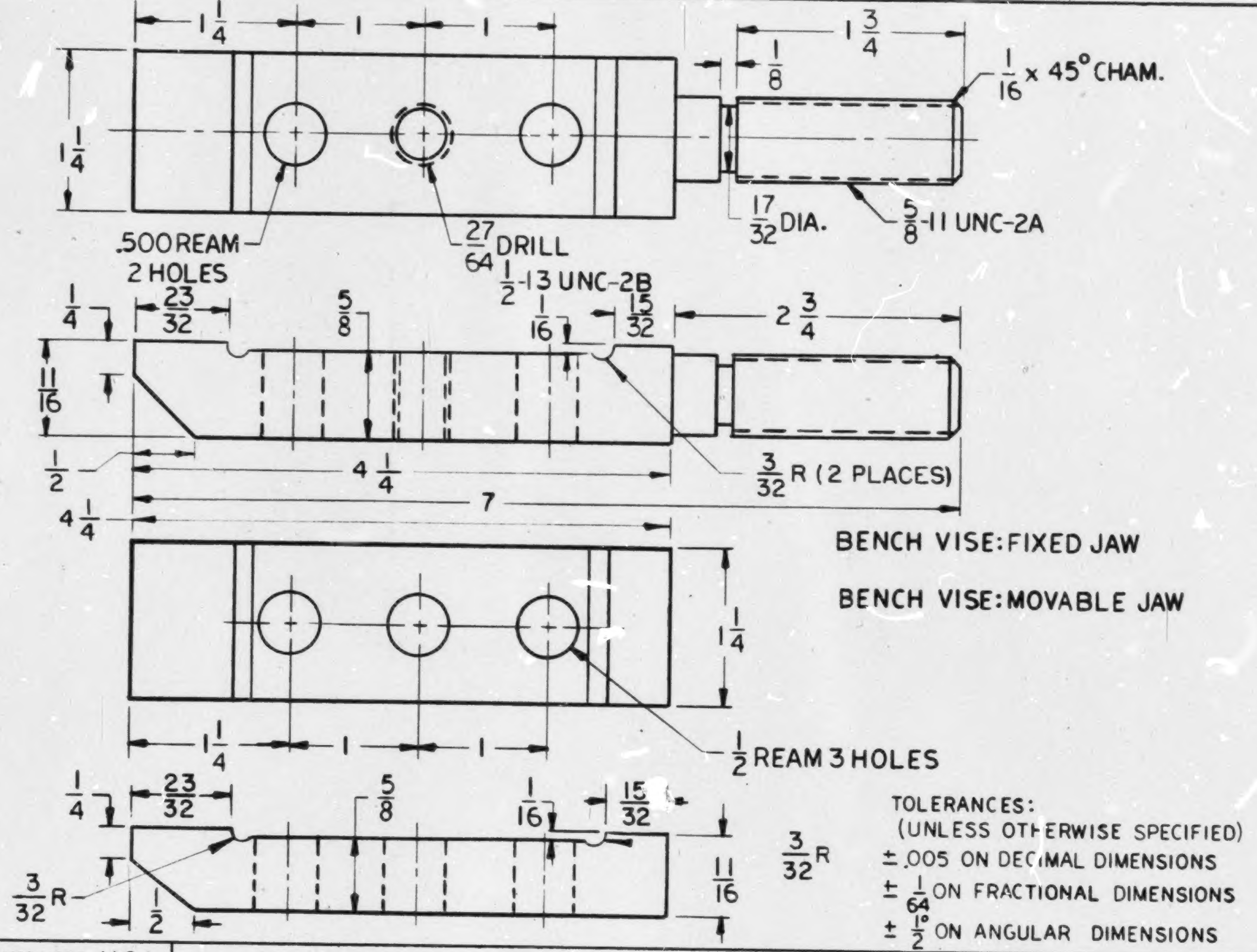
DRAWN BY: E.F.S.

SCALE: ——

BENCH VISE ASSEMBLY

DWG. NO. 15


$\frac{15}{32}$R (SPHER.)
$\frac{9}{16}$
$\frac{9}{16}$ DIA.
$\frac{15}{16}$ DIA.
$\frac{27}{64}$ DIA.
$\frac{1}{2}$-13 UNC-2A
$\frac{1}{16}$ × 45° CHAM.
$\frac{17}{64}$ DR.
$\frac{1}{8}$R
$\frac{1}{8}$
$1\frac{1}{2}$
$\frac{3}{16}$
$\frac{3}{4}$
$2\frac{3}{4}$
$5\frac{3}{16}$
BENCH VISE SCREW
$\frac{41}{64}$ DR.
$\frac{1}{16}$ × 45° CHAM.
$1\frac{1}{2}$ DIA.
WASHER
2 REQD.
$\frac{3}{16}$
$\frac{1}{16}$ × 45° CHAM.
$\frac{1}{2}$ DIA.
$3\frac{1}{2}$
GUIDE PIN
$\frac{5}{8}$-11 UNC-2B
$\frac{1}{8}$R
$1\frac{1}{2}$ DIA.
BENCH VISE NUT
$\frac{7}{8}$
MED. KNURL
TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
±.005 ON DECIMAL DIMENSIONS
$\pm\frac{1}{64}$ ON FRACTIONAL DIMENSIONS
±1° ON ANGULAR DIMENSIONS
$\frac{1}{16}$ × 45° CHAM. (TYP.)
FINE KNURL
$\frac{1}{4}$ DIA.
BENCH
VISE
HANDLE
PART A
$\frac{5}{8}$
$2\frac{5}{8}$
$\frac{11}{16}$
$\frac{7}{32}$ DIA.
$3\frac{15}{16}$
$\frac{7}{32}$ DRILL, CSK. ONE END
RIVET AT ASSEMBLY
$\frac{1}{2}$ DIA.
PART B
$\frac{5}{8}$
$\frac{1}{16}$ × 45° CHAM. (TYP.)
DRAWN BY: E.F.S.
SCALE: ——
BENCH VISE DETAILS
DWG. NO. 16



1 1/4
1
1
1 3/4
1/8
1/16 x 45° CHAM.
1 1/4
17/32 DIA.
5/8-11 UNC-2A
.500 REAM
2 HOLES
27/64 DRILL
1/2-13 UNC-2B
1/4
23/32
5/8
1/16
15/32
2 3/4
11/16
1/2
4 1/4
3/32 R (2 PLACES)
7
4 1/4
1 1/4
1 1/4
1
1
1/2 REAM 3 HOLES
1/4
23/32
5/8
1/16
15/32
3/32 R
3/32 R
1/2
11/16

BENCH VISE: FIXED JAW

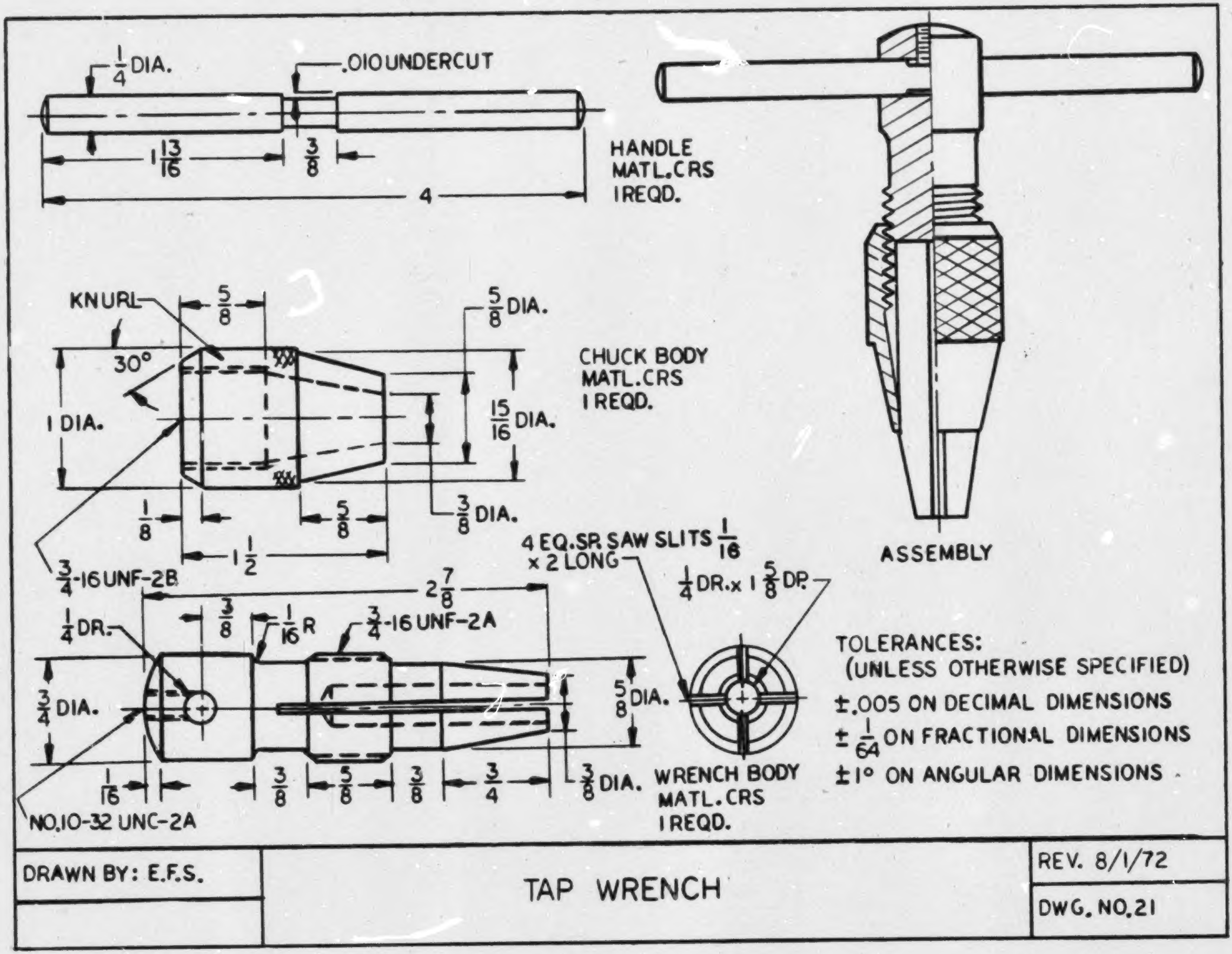
BENCH VISE: MOVABLE JAW

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
± .005 ON DECIMAL DIMENSIONS
± 1/64 ON FRACTIONAL DIMENSIONS
± 1/2° ON ANGULAR DIMENSIONS

DRAWN BY: V.C.L.
SCALE: ——

BENCH VISE
FIXED AND MOVABLE JAWS

DWG. NO. 17


$\frac{1}{4}$ DIA.
.010 UNDERCUT
$1\frac{13}{16}$
$\frac{3}{8}$
4
HANDLE
MATL. CRS
1 REQD.
KNURL
30°
$\frac{5}{8}$
1 DIA.
$\frac{5}{8}$ DIA.
$\frac{15}{16}$ DIA.
$\frac{3}{8}$ DIA.
$\frac{1}{8}$
$\frac{5}{8}$
$1\frac{1}{2}$
CHUCK BODY
MATL. CRS
1 REQD.
$\frac{3}{4}$-16 UNF-2B
$2\frac{7}{8}$
$\frac{1}{4}$ DR.
$\frac{3}{8}$
$\frac{1}{16}$ R
$\frac{3}{4}$-16 UNF-2A
$\frac{3}{4}$ DIA.
$\frac{5}{8}$ DIA.
$\frac{1}{16}$
$\frac{3}{8}$
$\frac{5}{8}$
$\frac{3}{8}$
$\frac{3}{4}$
$\frac{3}{8}$ DIA.
NO.10-32 UNC-2A
4 EQ.SP. SAW SLITS $\frac{1}{16}$ × 2 LONG
$\frac{1}{4}$ DR. × $1\frac{5}{8}$ DP.
WRENCH BODY
MATL. CRS
1 REQD.
ASSEMBLY

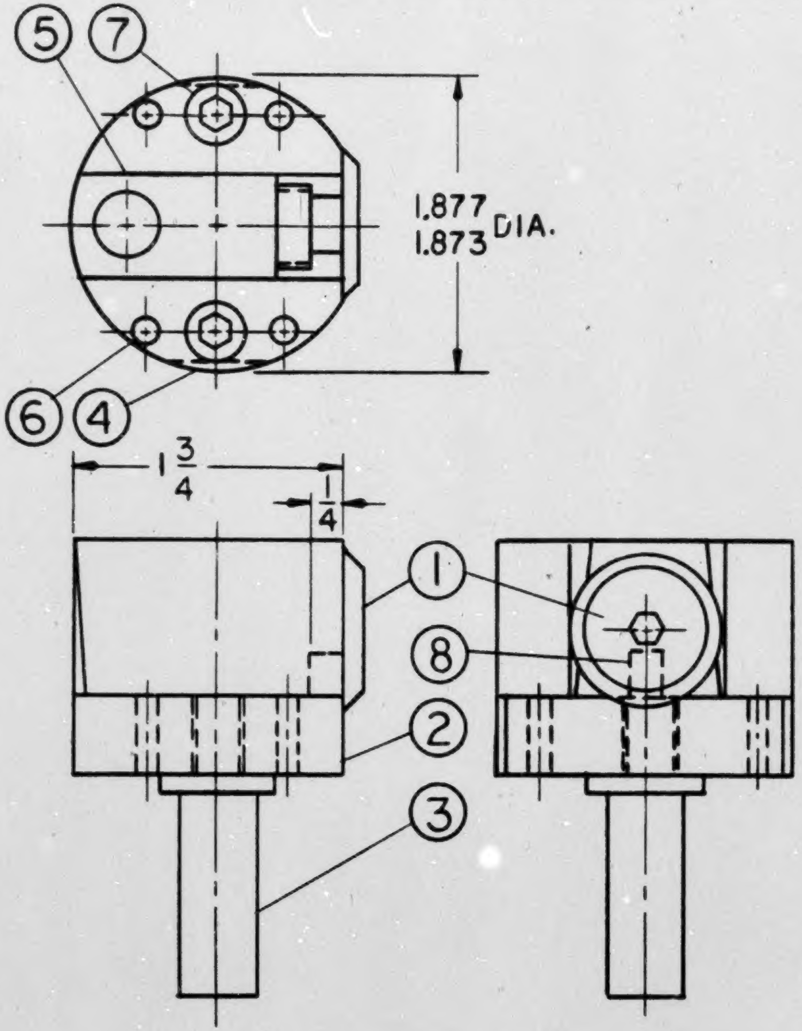
TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
±.005 ON DECIMAL DIMENSIONS
± $\frac{1}{64}$ ON FRACTIONAL DIMENSIONS
±1° ON ANGULAR DIMENSIONS

DRAWN BY: E.F.S.

TAP WRENCH

REV. 8/1/72

DWG. NO. 21



PARTS LIST

NO.	NAME	MATL.	REQD.
1	GRADUATED DIAL	C R S	1
2	PLATE	C R S	1
3	SHANK	C R S	1
4	DOVETAIL BLOCKS	C R S	2
5	DOVETAIL SLIDE	C R S	1
6	DOWEL PIN $\frac{3}{16}$ DIA. x $1\frac{1}{4}$	C R S	4
7	HEX. HD. CAP. SCR. $\frac{5}{16}$–18 UNC	C R S	2
8	STOP PIN	C R S	1

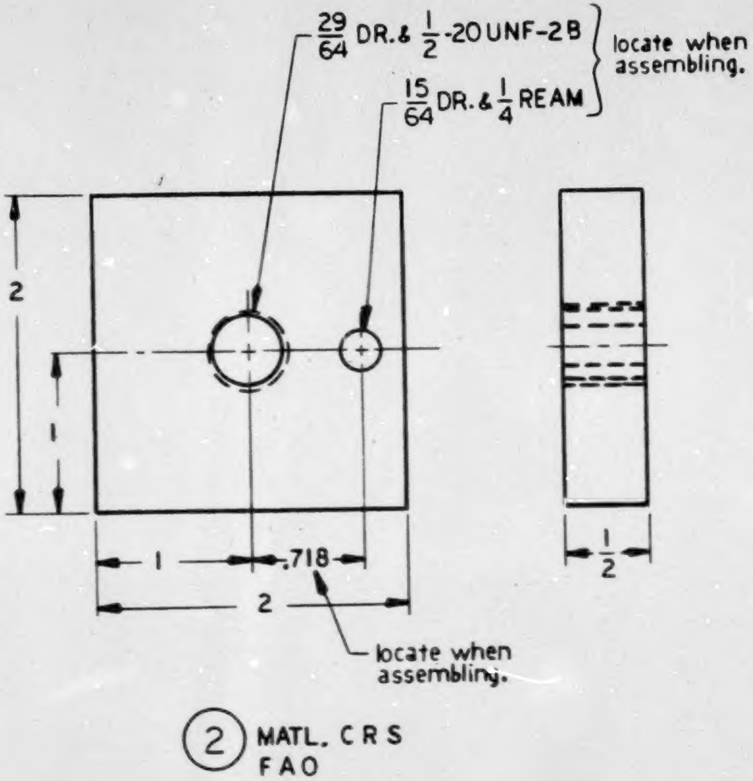
NOTES:

1. PARTS 2 AND 4 ARE MILLING MACHINE PROJECTS.
2. PARTS 6 AND 7 ARE PURCHASED.
3. PARTS 2, 4 AND 5 ARE ASSEMBLED TO A 2" SQ. AND THEN MACHINED ROUND.

DRAWN BY: E. F. S.
SCALE: ——

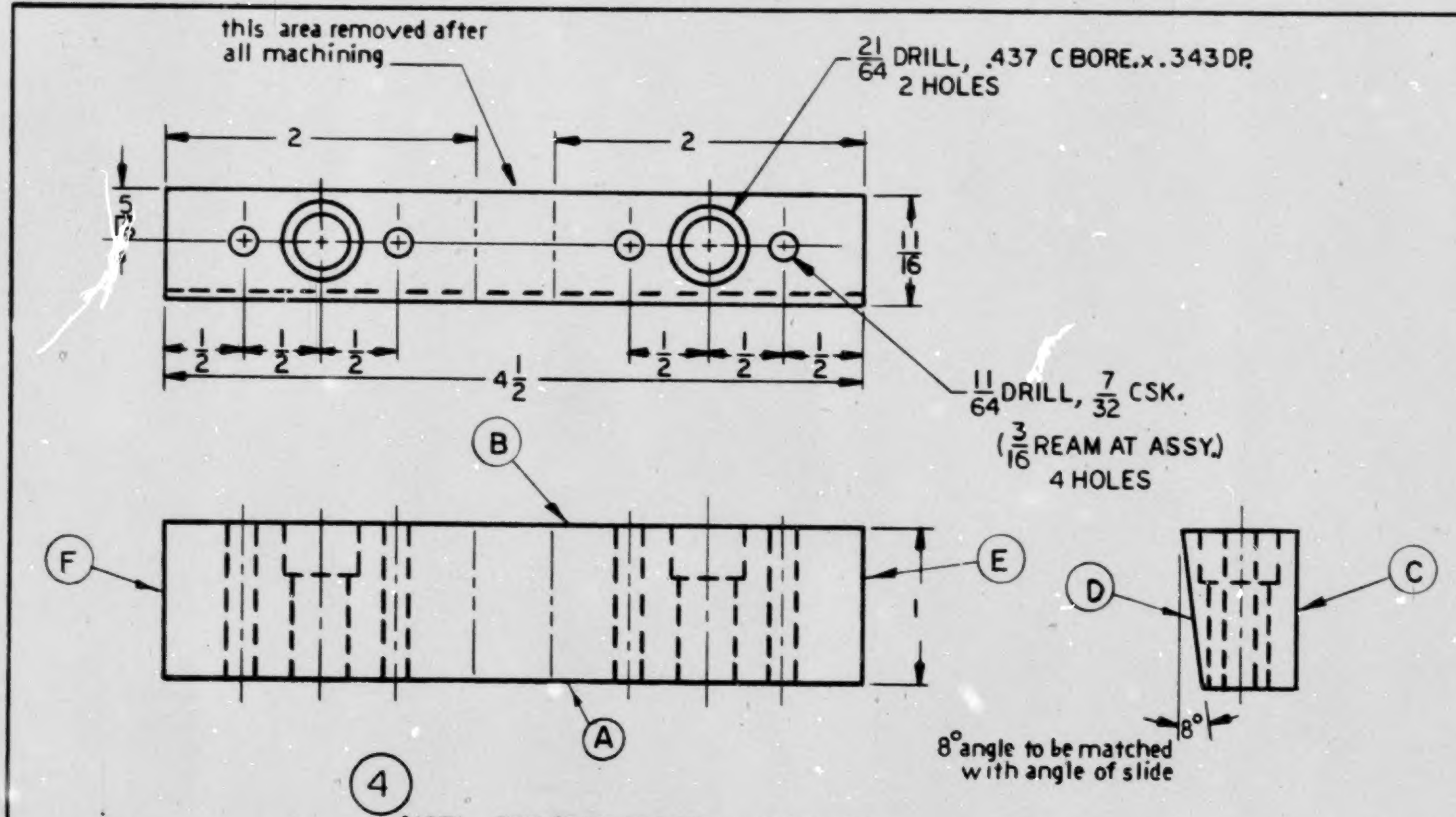
MICROMETER BORING HEAD
ASSEMBLY

DWG. NO. 22


$\frac{29}{64}$ DR. & $\frac{1}{2}$-20 UNF-2B
$\frac{15}{64}$ DR. & $\frac{1}{4}$ REAM
locate when assembling.
2
1
1
.718
2
$\frac{1}{2}$
locate when assembling.
② MATL. C R S
F A O

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
± .005 DECIMAL
± $\frac{1}{64}$ FRACTIONAL
± $\frac{1}{2}$° ANGULAR

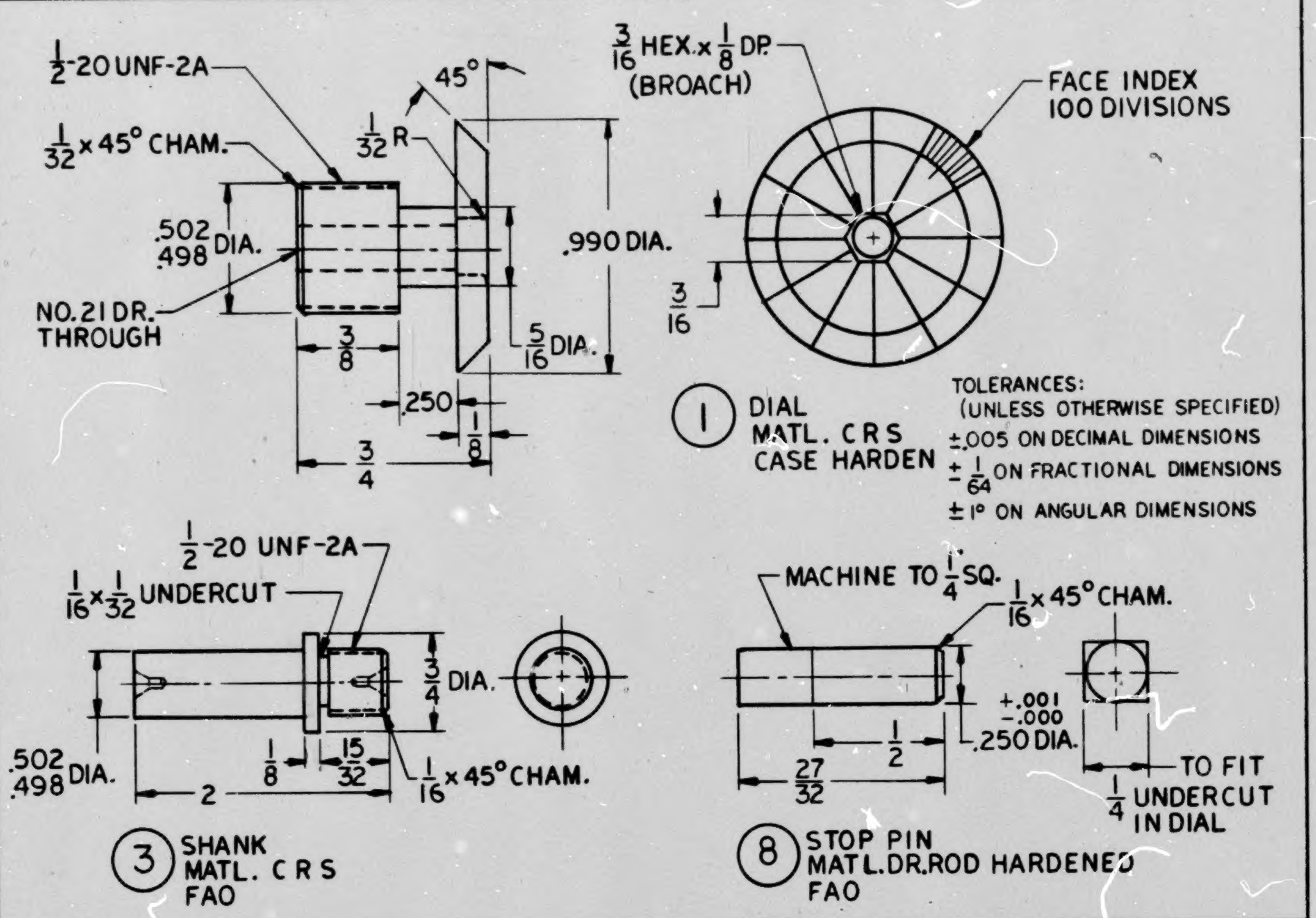
DRAW BY: E. F. S.	MICROMETER BORING HEAD PLATE	
SCALE: ——		DWG. NO. 22.1


this area removed after all machining
$\frac{21}{64}$ DRILL, .437 C BORE.x.343 DP.
2 HOLES
2
2
$\frac{5}{32}$
$\frac{11}{16}$
$\frac{1}{2}$
$\frac{1}{2}$
$\frac{1}{2}$
$4\frac{1}{2}$
$\frac{1}{2}$
$\frac{1}{2}$
$\frac{1}{2}$
$\frac{11}{64}$ DRILL, $\frac{7}{32}$ CSK.
($\frac{3}{16}$ REAM AT ASSY.)
4 HOLES
B
F
E
D
C
A
8°
8° angle to be matched with angle of slide
4

MATL. CRS (SAE 1020) or PHOSPHOR
BRONZE (SAE 64)
FAO
2 REQD.

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
± .005 DECIMAL
± $\frac{1}{64}$ FRACTIONAL
± $\frac{1}{2}$° ANGULAR

DRAWN BY: E.F.S.	MICROMETER BORING HEAD DOVETAIL BLOCKS	
SCALE: ——		DWG. NO. 22.2

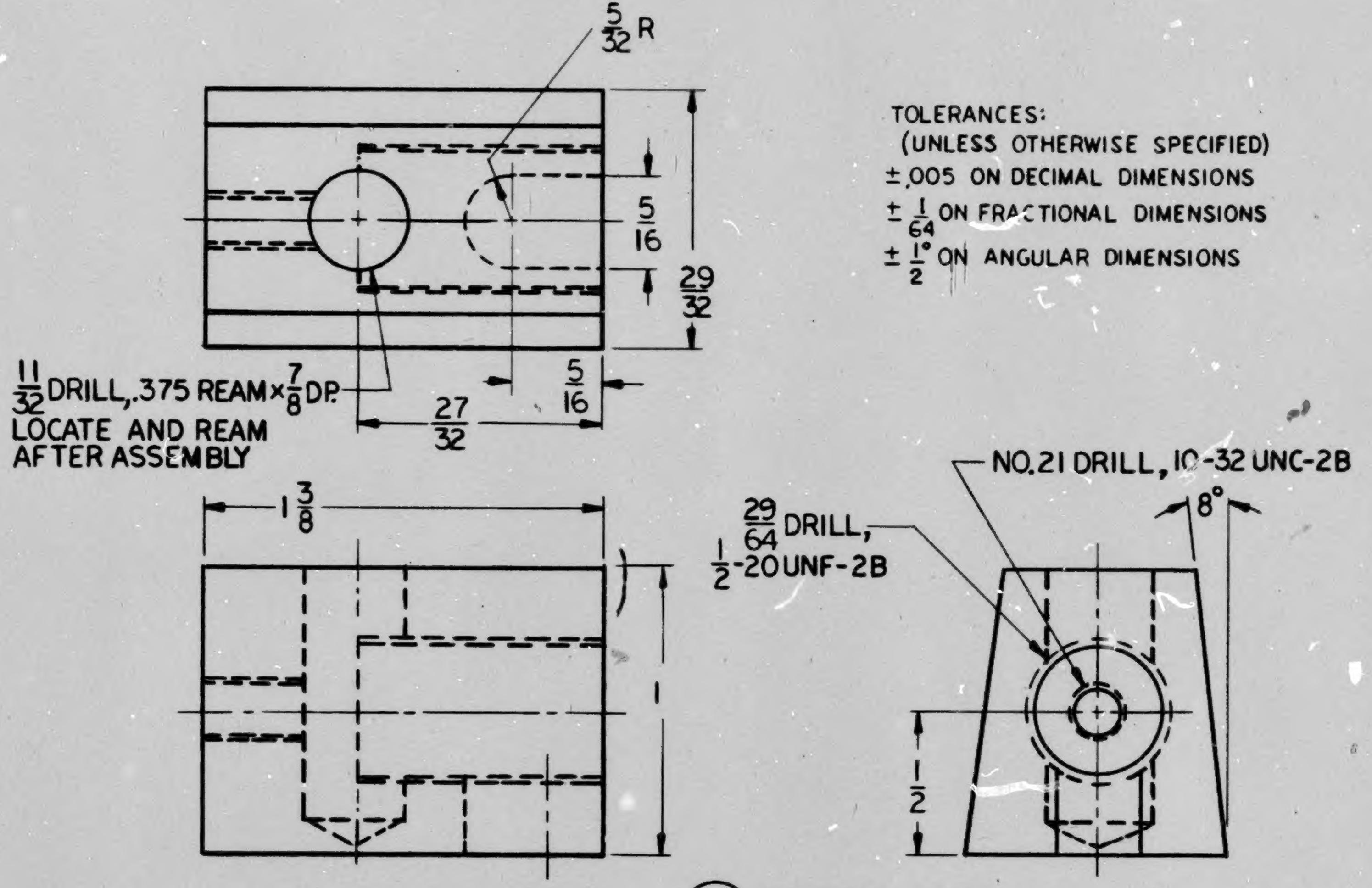

$\frac{1}{2}$-20 UNF-2A
$\frac{1}{32}$ x 45° CHAM.
$\frac{1}{32}$ R
45°
.502 .498 DIA.
NO. 21 DR. THROUGH
.990 DIA.
$\frac{5}{16}$ DIA.
$\frac{3}{8}$
.250
$\frac{1}{8}$
$\frac{3}{4}$
$\frac{3}{16}$ HEX. x $\frac{1}{8}$ DP. (BROACH)
FACE INDEX 100 DIVISIONS
$\frac{3}{16}$
① DIAL MATL. C R S CASE HARDEN
$\frac{1}{2}$-20 UNF-2A
$\frac{1}{16}$ x $\frac{1}{32}$ UNDERCUT
$\frac{3}{4}$ DIA.
.502 .498 DIA.
2
$\frac{1}{8}$
$\frac{15}{32}$
$\frac{1}{16}$ x 45° CHAM.
③ SHANK MATL. C R S FAO
MACHINE TO $\frac{1}{4}$" SQ.
$\frac{1}{16}$ x 45° CHAM.
+.001 -.000 .250 DIA.
$\frac{1}{2}$
$\frac{27}{32}$
TO FIT $\frac{1}{4}$ UNDERCUT IN DIAL
⑧ STOP PIN MATL. DR. ROD HARDENED FAO

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
±.005 ON DECIMAL DIMENSIONS
$\pm\frac{1}{64}$ ON FRACTIONAL DIMENSIONS
±1° ON ANGULAR DIMENSIONS

DRAWN BY : E.F.S.
SCALE : —

MICROMETER BORING HEAD
DIAL, SHANK, AND STOP PIN

DWG. NO. 23

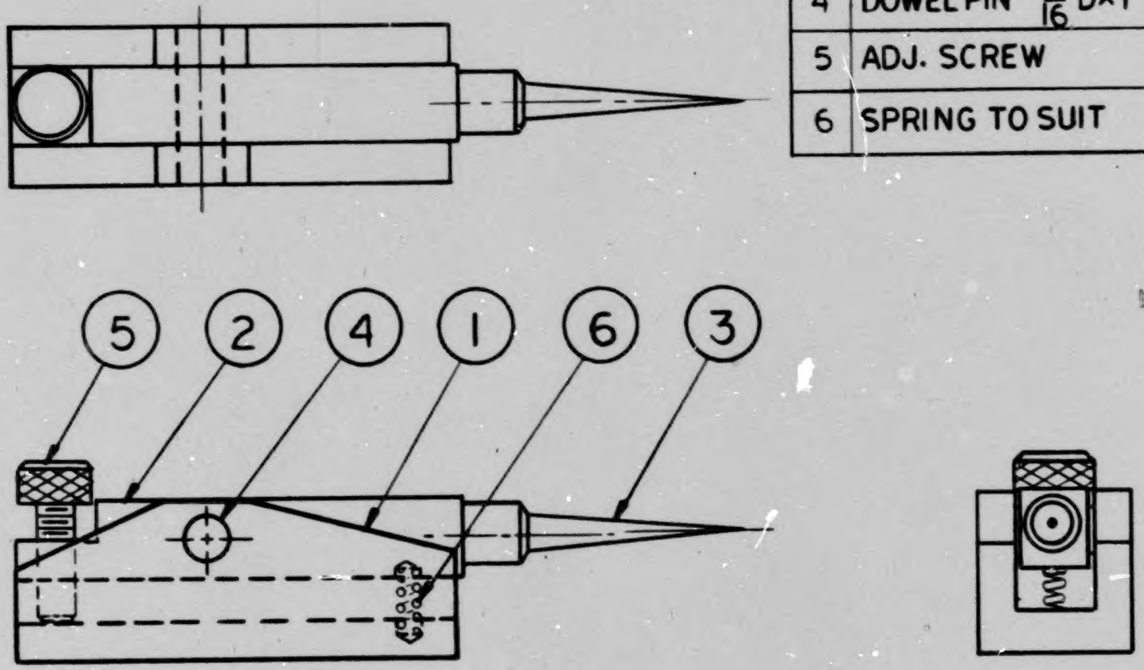

5/32 R
5/16
29/32
11/32 DRILL, .375 REAM × 7/8 DP.
LOCATE AND REAM
AFTER ASSEMBLY
27/32
5/16
1 3/8
29/64 DRILL,
1/2-20 UNF-2B
NO.21 DRILL, 10-32 UNC-2B
8°
1/2

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
± .005 ON DECIMAL DIMENSIONS
± 1/64 ON FRACTIONAL DIMENSIONS
± 1/2° ON ANGULAR DIMENSIONS

⑤ DOVETAIL SLIDE
MATL. CRS
FAO

DRAWN BY: E.F.S.	MICROMETER BORING HEAD DOVETAIL SLIDE	
SCALE: ——		DWG. NO. 24

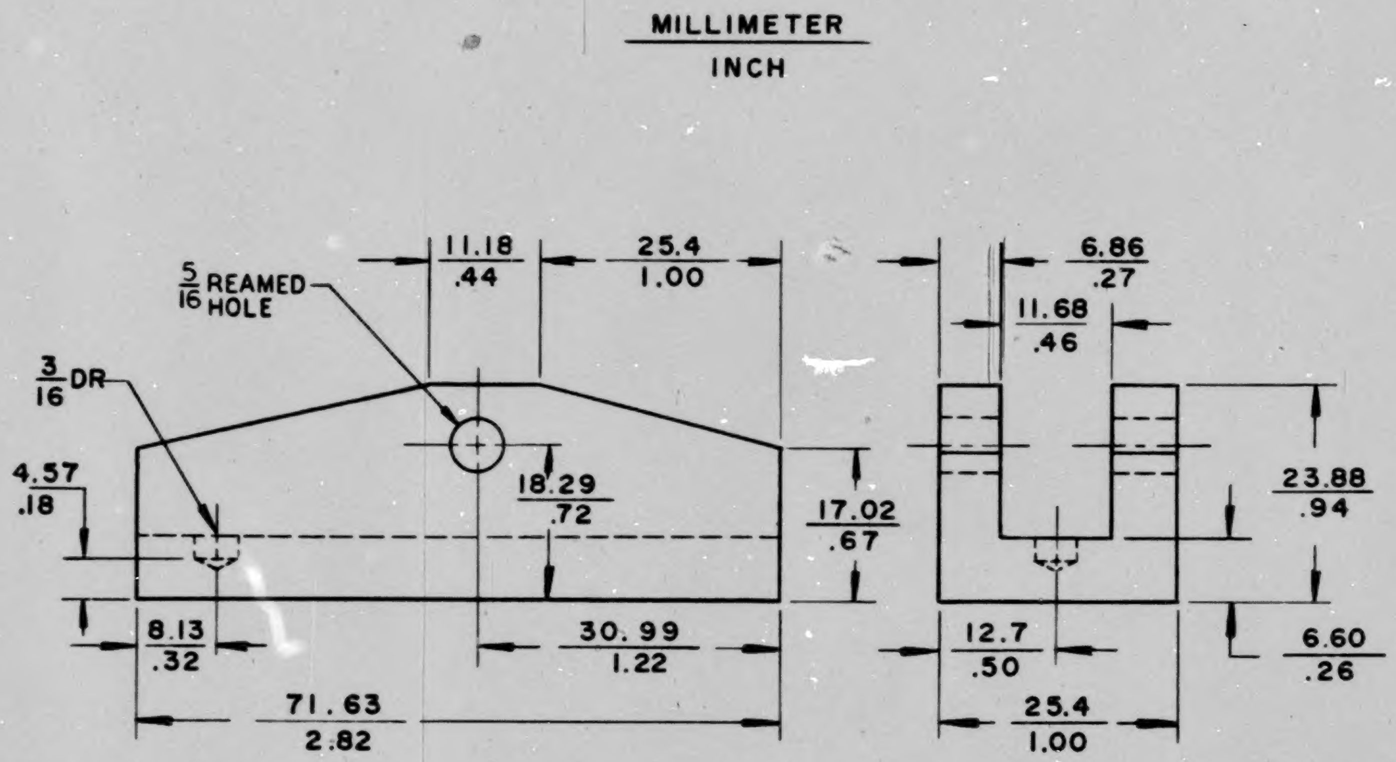
PARTS LIST			
NO.	NAME	MATL.	REQD.
1	BASE $\frac{15}{16} \times 1 \times 2\frac{7}{8}$	C R S	1
2	ADJUSTMENT BAR	C R S	1
3	SCRIBER PT. $\frac{3}{8}$ D $\times 2\frac{5}{8}$	D R	1
4	DOWEL PIN $\frac{5}{16}$ D $\times 1$	C R S	1
5	ADJ. SCREW	C R S	1
6	SPRING TO SUIT	STD.	1



DRAWN BY: E.F.S.
SCALE: ——

SURFACE GAGE
ASSEMBLY

DWG.NO. 25

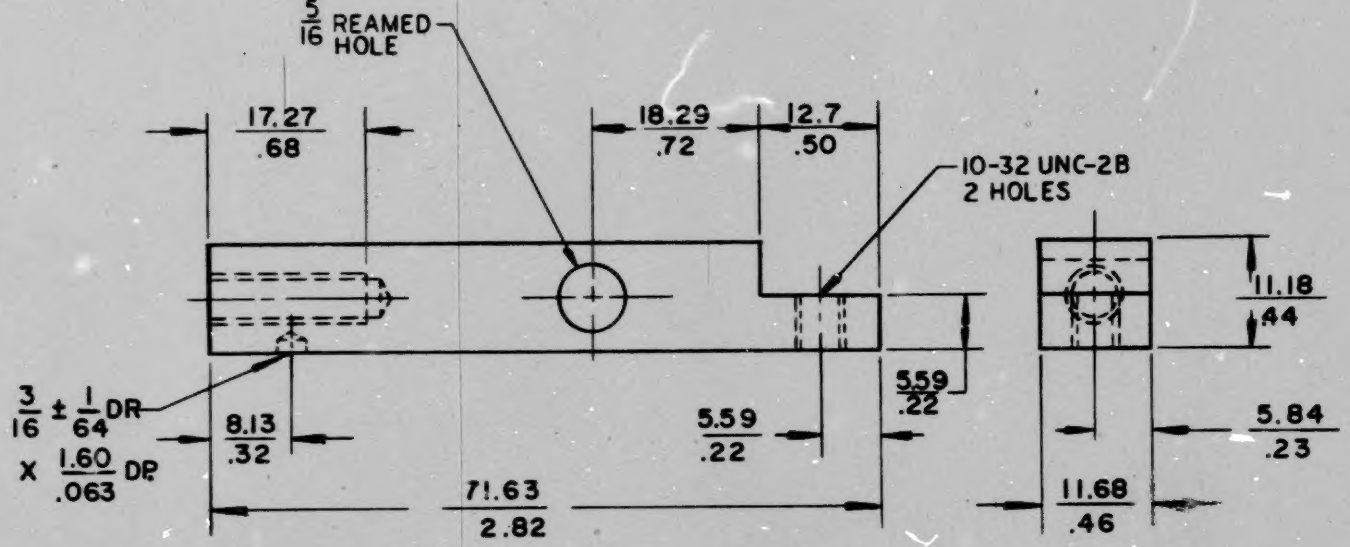

MILLIMETER
INCH
5/16 REAMED HOLE
3/16 DR
11.18 / .44
25.4 / 1.00
6.86 / .27
11.68 / .46
4.57 / .18
18.29 / .72
17.02 / .67
23.88 / .94
8.13 / .32
30.99 / 1.22
12.7 / .50
6.60 / .26
71.63 / 2.82
25.4 / 1.00

MATERIAL: CRS

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
± 0.4 MILLIMETER
± .005 INCH

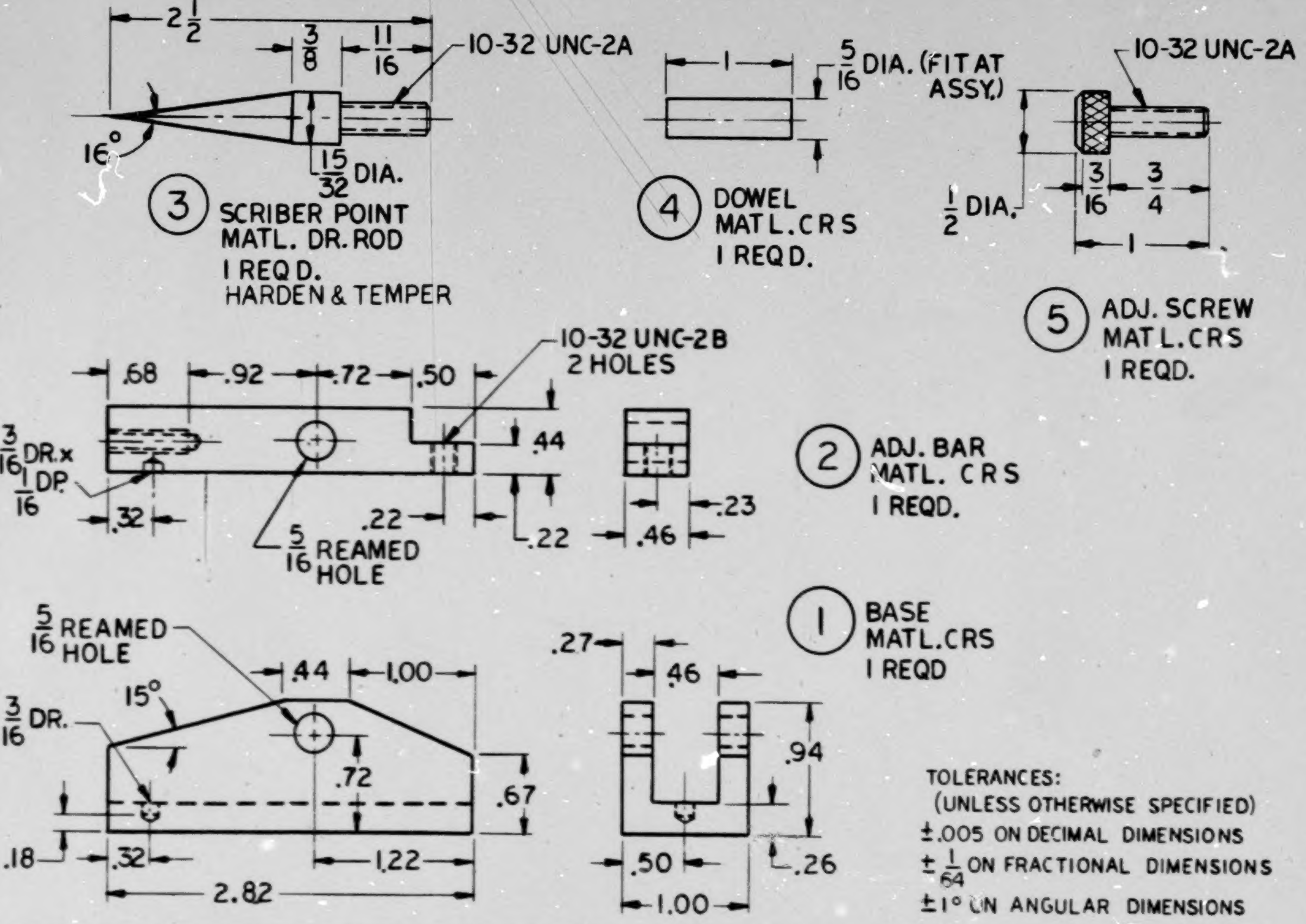
DRAWN BY: V.C.L.	SURFACE GAGE BASE (DUAL DIMENSIONING)	
SCALE: —		DWG.NO. 25.1

MILLIMETER
INCH


5/16 REAMED HOLE
17.27 / .68
18.29 / .72
12.7 / .50
10-32 UNC-2B
2 HOLES
11.18 / .44
3/16 ± 1/64 DR
X 1.60/.063 DP.
8.13 / .32
5.59 / .22
5.59 / .22
5.84 / .23
71.63 / 2.82
11.68 / .46

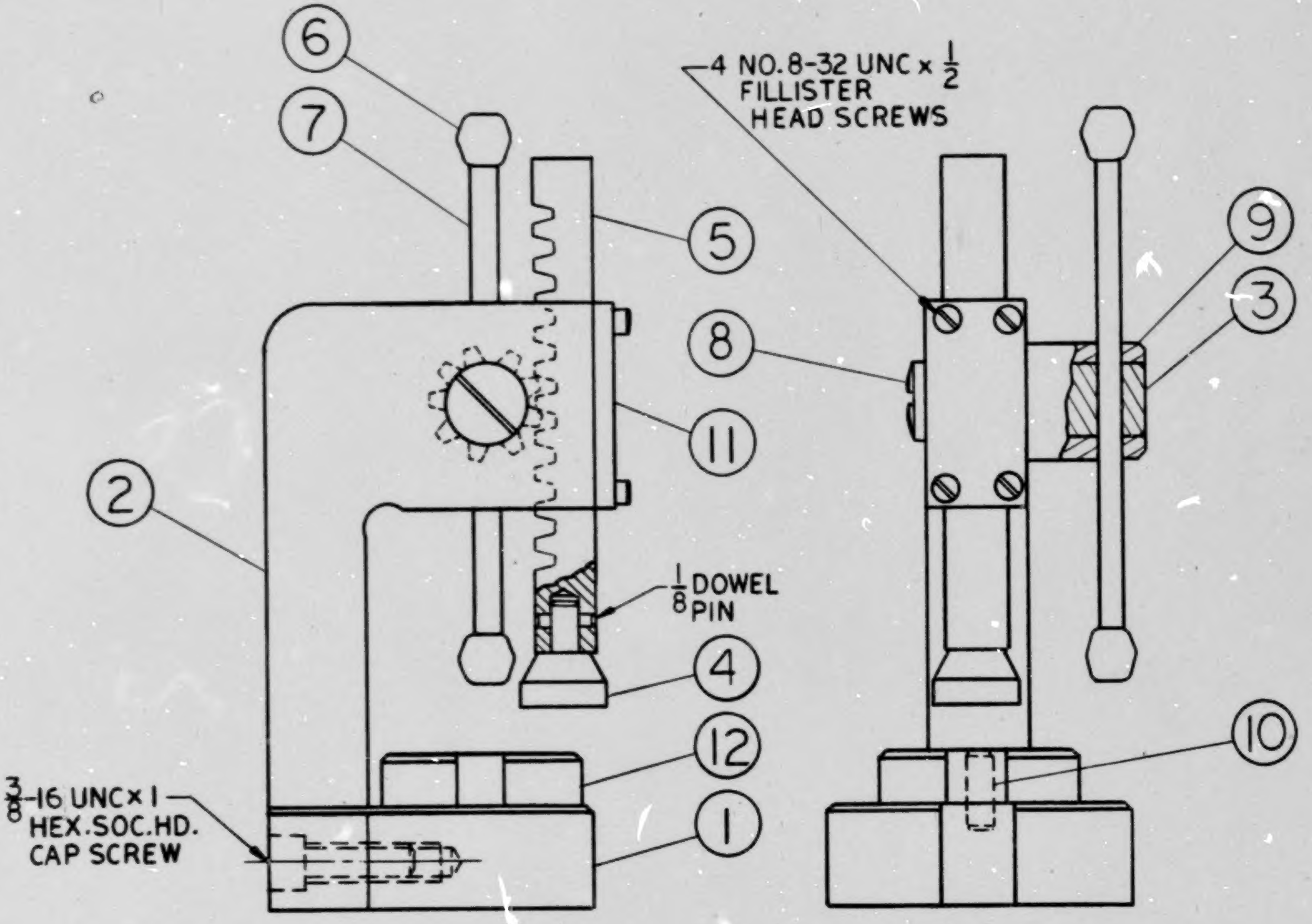
MATERIAL: CRS
TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
± 0.4 MILLIMETER
± .005 INCH

DRAWN BY: V.C.L.	SURFACE GAGE ADJUSTMENT BAR (DUAL DIMENSIONING)	
SCALE: ——		DWG.NO. 25.2


2 1/2
3/8
11/16
10-32 UNC-2A
16°
15/32 DIA.
③ SCRIBER POINT
MATL. DR. ROD
1 REQD.
HARDEN & TEMPER
1
5/16 DIA. (FIT AT ASSY.)
④ DOWEL
MATL. CRS
1 REQD.
10-32 UNC-2A
1/2 DIA.
3/16
3/4
1
⑤ ADJ. SCREW
MATL. CRS
1 REQD.
.68
.92
.72
.50
10-32 UNC-2B
2 HOLES
3/16 DR. x 1/16 DP.
.44
.32
.22
.22
5/16 REAMED HOLE
.23
.46
② ADJ. BAR
MATL. CRS
1 REQD.
5/16 REAMED HOLE
.44
1.00
15°
3/16 DR.
.72
.67
.18
.32
1.22
2.82
.27
.46
.94
.50
.26
1.00
① BASE
MATL. CRS
1 REQD

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
±.005 ON DECIMAL DIMENSIONS
± $\frac{1}{64}$ ON FRACTIONAL DIMENSIONS
±1° ON ANGULAR DIMENSIONS

DRAWN BY: E.F.S.	SURFACE GAGE DETAILS	REV. 9/15/74
SCALE: ——		DWG. NO. 26

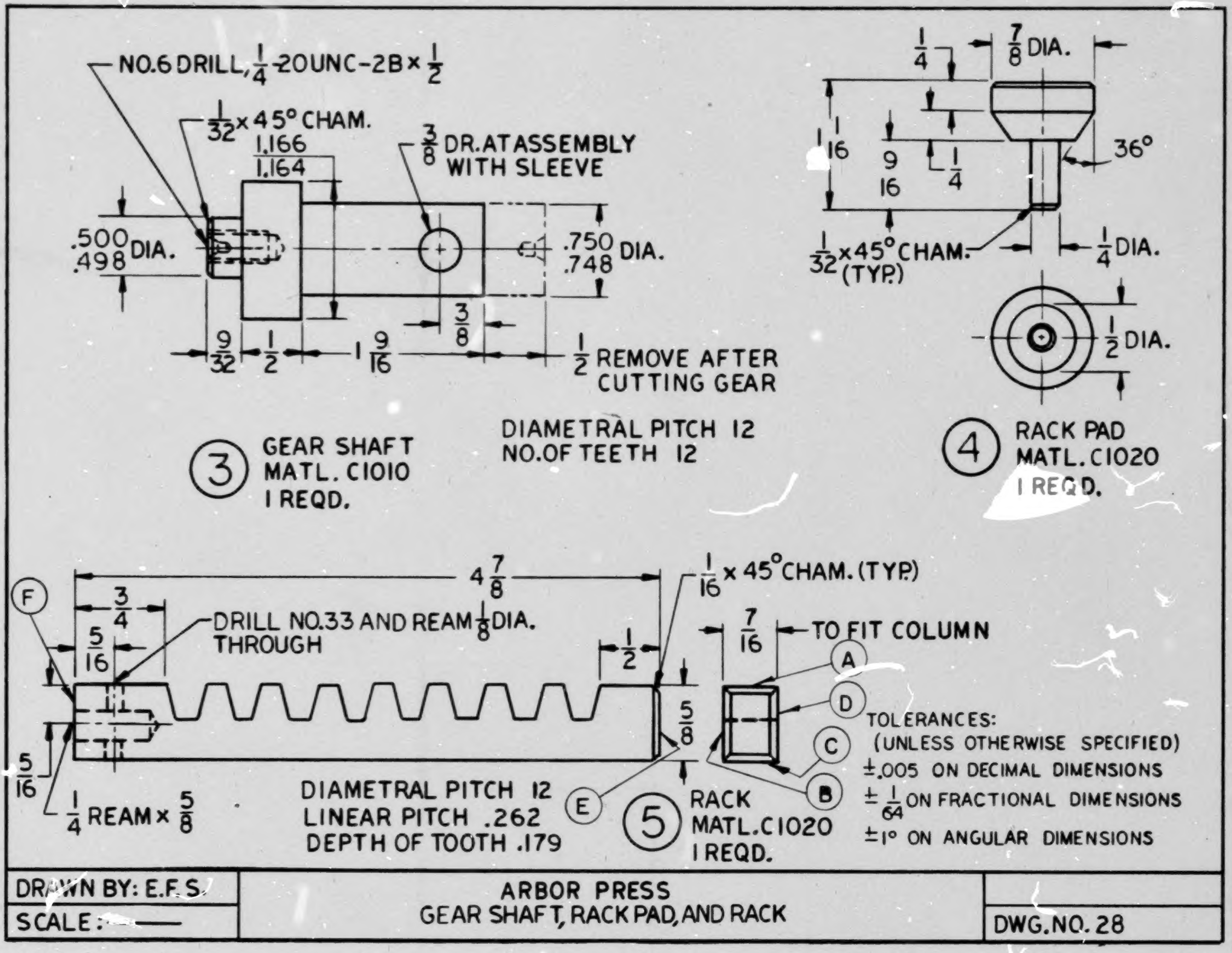

6
7
5
11
2
8
4 NO. 8-32 UNC × $\frac{1}{2}$
FILLISTER
HEAD SCREWS
9
3
$\frac{1}{8}$ DOWEL PIN
4
12
1
10
$\frac{3}{8}$-16 UNC × 1
HEX. SOC. HD.
CAP SCREW

DRAWN BY: E.F.S.

SCALE: ——

ARBOR PRESS
ASSEMBLY

DWG. NO. 27

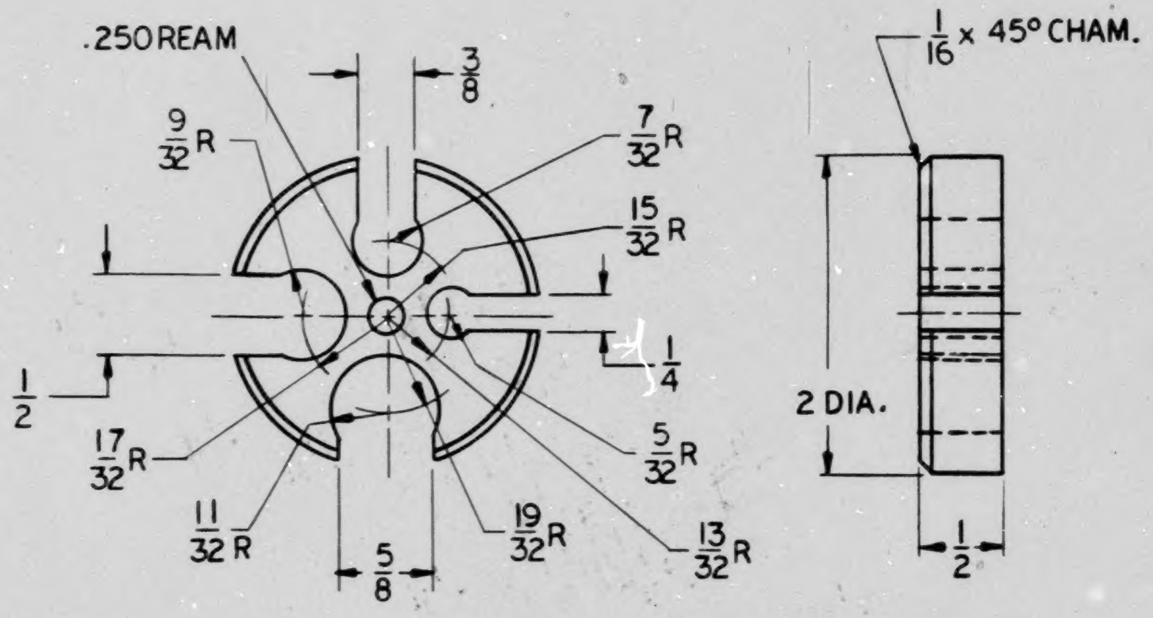

NO.6 DRILL, 1/4-20UNC-2B × 1/2
1/32 × 45° CHAM.
1.166
1.164
3/8 DR. AT ASSEMBLY WITH SLEEVE
.500
.498 DIA.
.750
.748 DIA.
9/32
1/2
1 9/16
3/8
1/2 REMOVE AFTER CUTTING GEAR
3
GEAR SHAFT
MATL. C1010
1 REQD.
DIAMETRAL PITCH 12
NO. OF TEETH 12
1/4
7/8 DIA.
1 1/16
9/16
1/4
36°
1/32 × 45° CHAM. (TYP.)
1/4 DIA.
1/2 DIA.
4
RACK PAD
MATL. C1020
1 REQD.
4 7/8
3/4
5/16
DRILL NO.33 AND REAM 1/8 DIA. THROUGH
1/2
1/16 × 45° CHAM. (TYP.)
7/16
TO FIT COLUMN
5/8
F
E
A
D
C
B
5/16
1/4 REAM × 5/8
DIAMETRAL PITCH 12
LINEAR PITCH .262
DEPTH OF TOOTH .179
5
RACK
MATL. C1020
1 REQD.

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
±.005 ON DECIMAL DIMENSIONS
± 1/64 ON FRACTIONAL DIMENSIONS
±1° ON ANGULAR DIMENSIONS

DRAWN BY: E.F.S.
SCALE: ——

ARBOR PRESS
GEAR SHAFT, RACK PAD, AND RACK

DWG. NO. 28

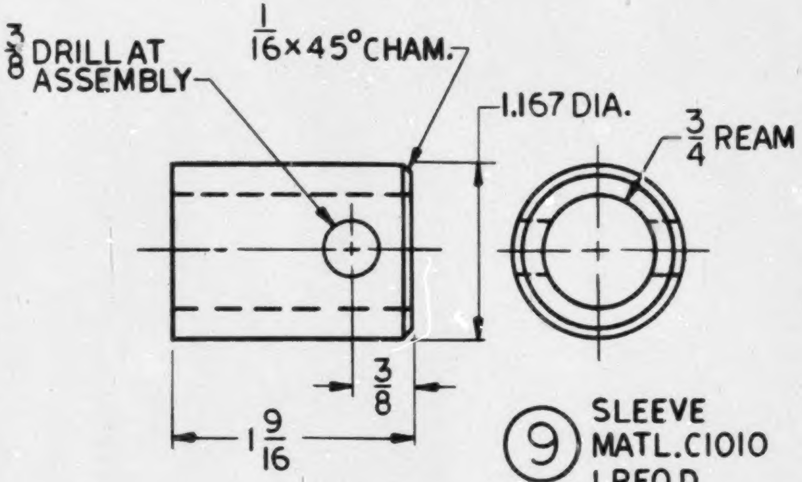

.250 REAM
$\frac{3}{8}$
$\frac{9}{32}$R
$\frac{7}{32}$R
$\frac{15}{32}$R
$\frac{1}{2}$
$\frac{1}{4}$
$\frac{17}{32}$R
$\frac{5}{32}$R
$\frac{11}{32}$R
$\frac{19}{32}$R
$\frac{13}{32}$R
$\frac{5}{8}$
$\frac{1}{16}$ x 45° CHAM.
2 DIA.
$\frac{1}{2}$

⑫ MATL. C1020
1 REQD.

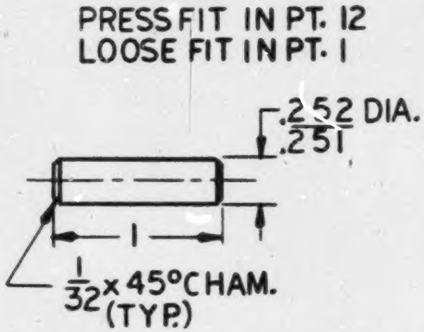
NOTE:
COUNTERSINK ALL HOLES
TOP AND BOTTOM $\frac{1}{32}$ DEEP
BEFORE SLOTTING.

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
± .005 ON DECIMAL DIMENSIONS
± $\frac{1}{64}$ ON FRACTIONAL DIMENSIONS
± 1° ON ANGULAR DIMENSIONS

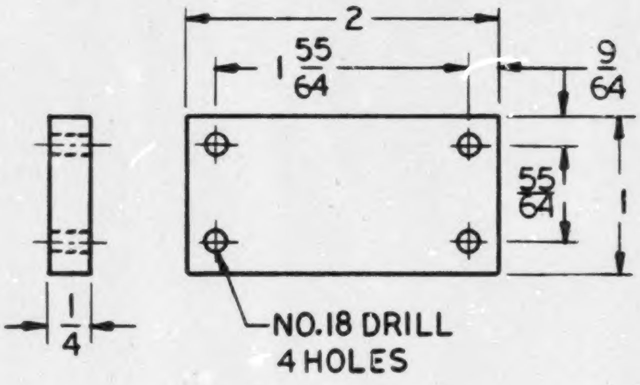
DRAWN BY: E.F.S.	ARBOR PRESS TABLE	
SCALE: ———		DWG. NO. 29


$\frac{3}{8}$ DRILL AT ASSEMBLY
$\frac{1}{16}$ × 45° CHAM.
1.167 DIA.
$\frac{3}{4}$ REAM
$\frac{3}{8}$
$1\frac{9}{16}$

⑨ SLEEVE
MATL. C1010
1 REQD.


PRESS FIT IN PT. 12
LOOSE FIT IN PT. 1
$\frac{.252}{.251}$ DIA.
1
$\frac{1}{32}$ × 45° CHAM. (TYP.)

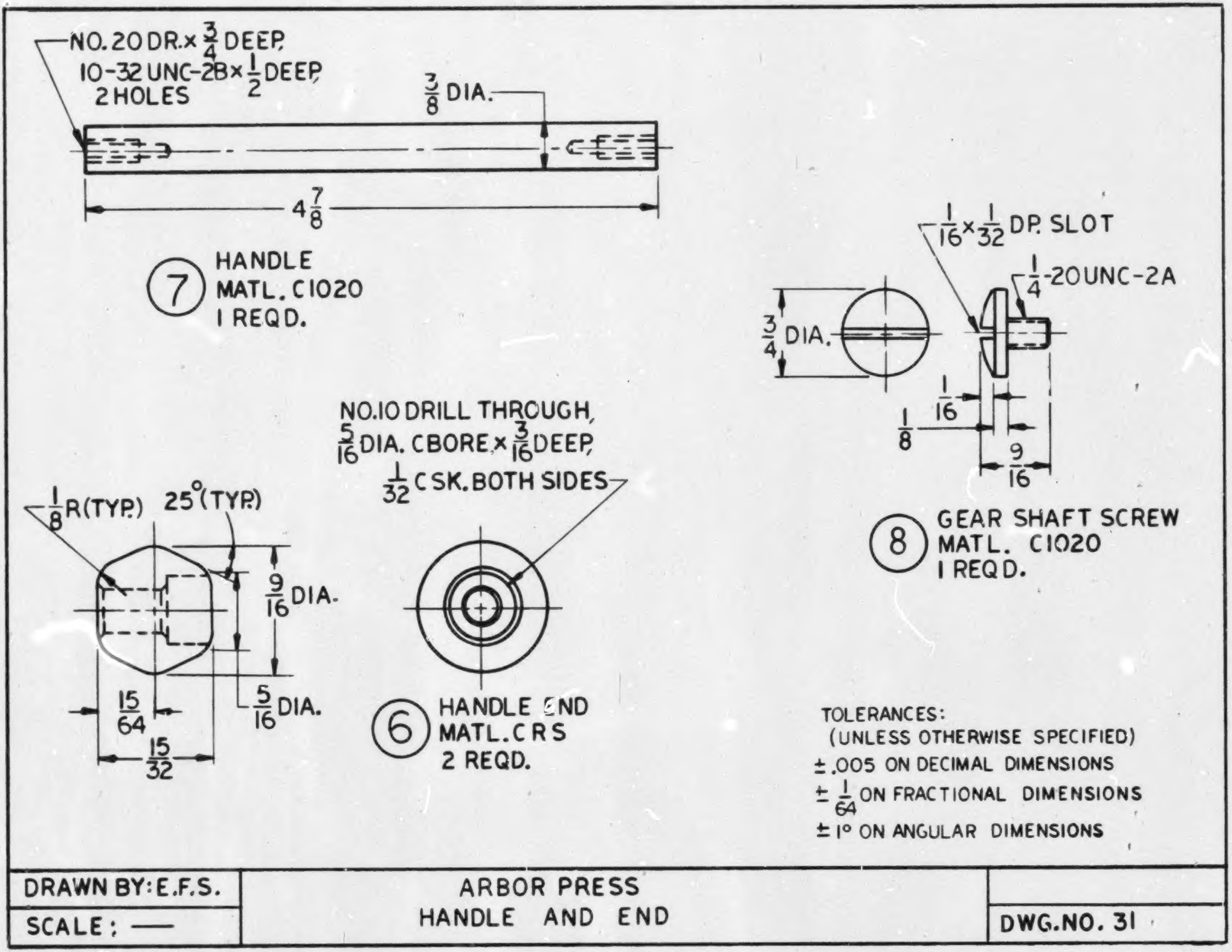
⑩ TABLE PIN
MATL. C1020
1 REQD.


2
$1\frac{55}{64}$
$\frac{9}{64}$
$\frac{55}{64}$
1
$\frac{1}{4}$
NO. 18 DRILL
4 HOLES

⑪ COVER PLATE
MAT L. C1010
1 REQD.

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
± .005 ON DECIMAL DIMENSIONS
± $\frac{1}{64}$ ON FRACTIONAL DIMENSIONS
± 1° ON ANGULAR DIMENSIONS

DRAWN BY: E.F.S.	ARBOR PRESS SLEEVE, TABLE PIN, AND COVER PLATE	
SCALE: ——		DWG. NO. 30

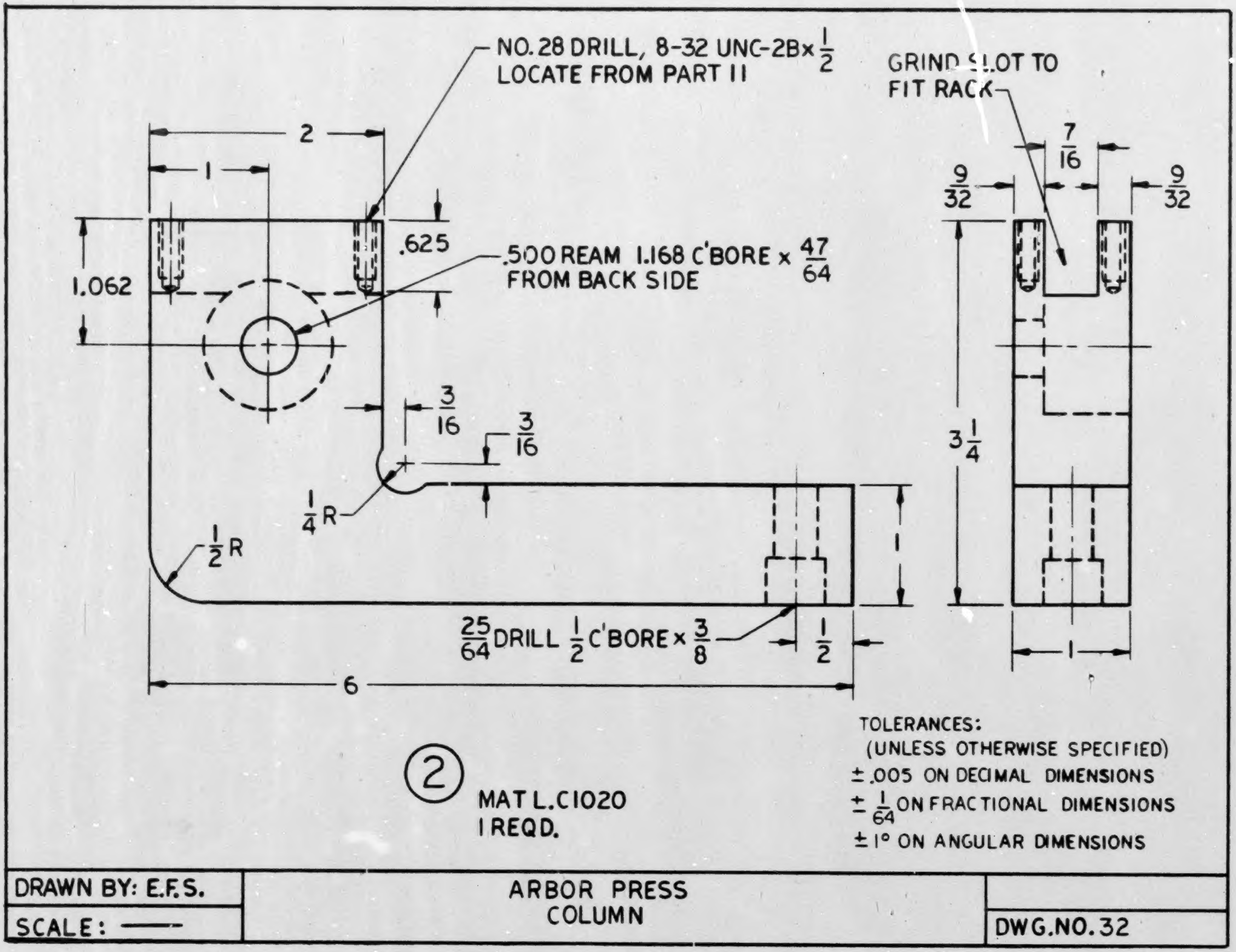

NO. 20 DR. × 3/4 DEEP, 10-32 UNC-2B × 1/2 DEEP, 2 HOLES
3/8 DIA.
4 7/8
⑦ HANDLE MATL. C1020 1 REQD.
1/16 × 1/32 DP. SLOT
1/4-20UNC-2A
3/4 DIA.
1/16
1/8
9/16
⑧ GEAR SHAFT SCREW MATL. C1020 1 REQD.
NO.10 DRILL THROUGH, 5/16 DIA. CBORE × 3/16 DEEP, 1/32 CSK. BOTH SIDES
1/8 R (TYP.)
25° (TYP.)
9/16 DIA.
5/16 DIA.
15/64
15/32
⑥ HANDLE END MATL. C R S 2 REQD.

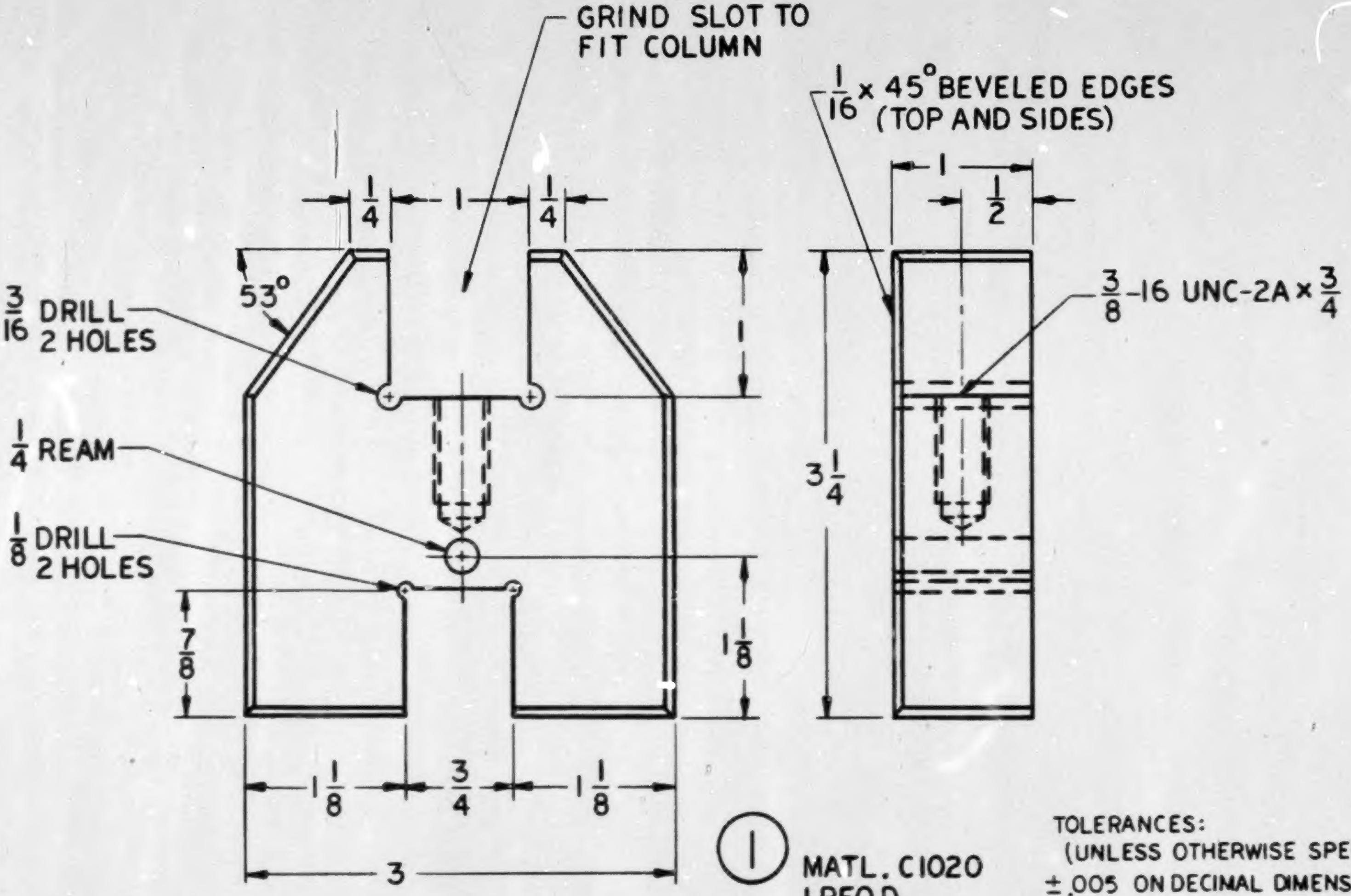
TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
±.005 ON DECIMAL DIMENSIONS
± $\frac{1}{64}$ ON FRACTIONAL DIMENSIONS
±1° ON ANGULAR DIMENSIONS

DRAWN BY: E.F.S.
SCALE: —

ARBOR PRESS
HANDLE AND END

DWG. NO. 31

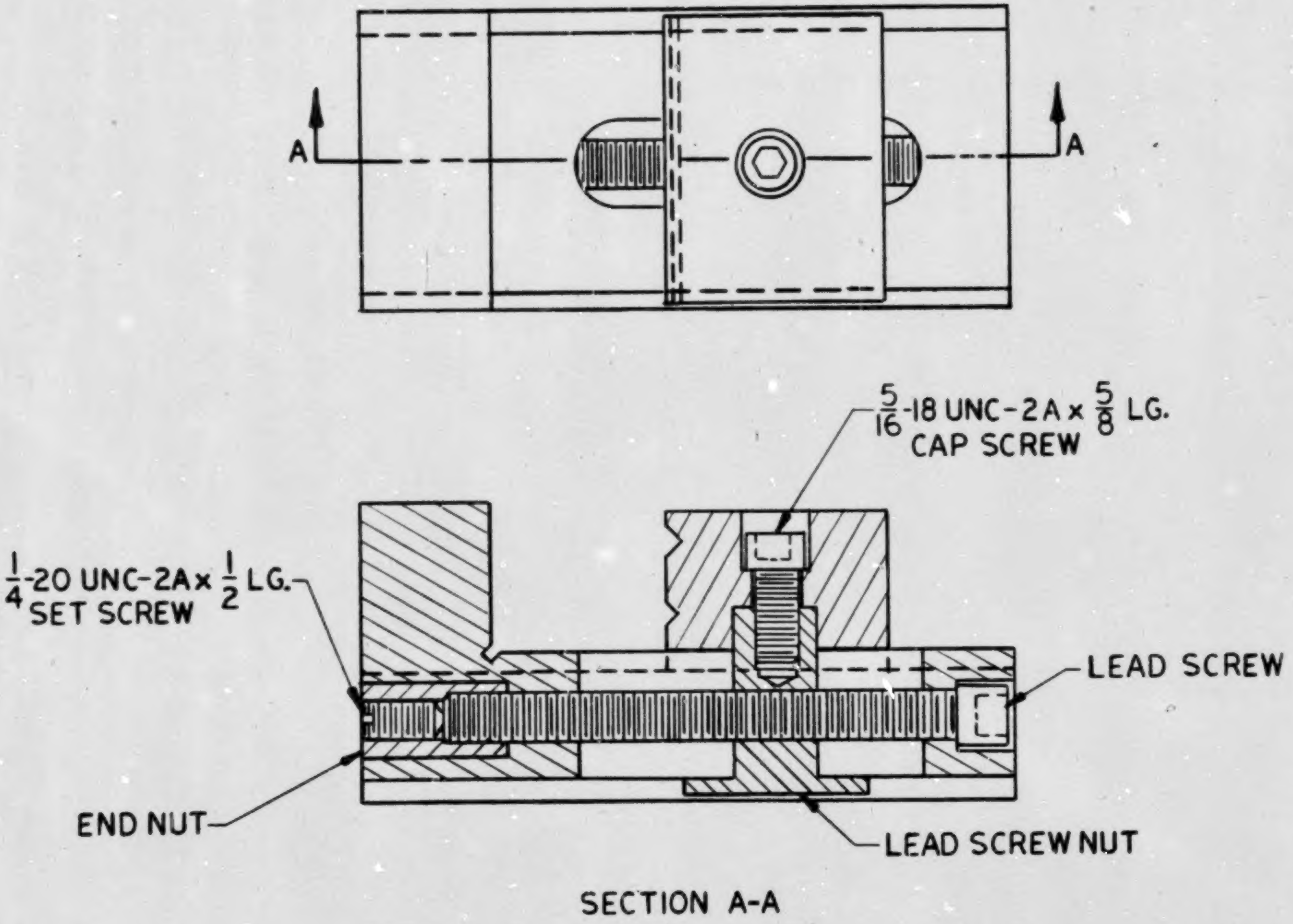

NO. 28 DRILL, 8-32 UNC-2B× 1/2
LOCATE FROM PART 11
GRIND SLOT TO
FIT RACK
2
1
.625
1.062
.500 REAM 1.168 C'BORE × 47/64
FROM BACK SIDE
7/16
9/32
9/32
3/16
3/16
1/4 R
1/2 R
3 1/4
25/64 DRILL 1/2 C'BORE × 3/8
1/2
1
6
②
MAT L. C1020
1 REQD.
TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
± .005 ON DECIMAL DIMENSIONS
± 1/64 ON FRACTIONAL DIMENSIONS
± 1° ON ANGULAR DIMENSIONS
DRAWN BY: E.F.S.
SCALE: ——
ARBOR PRESS
COLUMN
DWG. NO. 32


GRIND SLOT TO FIT COLUMN
$\frac{1}{16}$ x 45° BEVELED EDGES (TOP AND SIDES)
$\frac{1}{4}$
1
$\frac{1}{4}$
1
$\frac{1}{2}$
53°
$\frac{3}{16}$ DRILL 2 HOLES
$\frac{1}{4}$ REAM
$\frac{1}{8}$ DRILL 2 HOLES
$\frac{3}{8}$-16 UNC-2A x $\frac{3}{4}$
$3\frac{1}{4}$
$1\frac{1}{8}$
$\frac{7}{8}$
$1\frac{1}{8}$
$\frac{3}{4}$
$1\frac{1}{8}$
3

① MATL. C1020
1 REQ D.

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
±.005 ON DECIMAL DIMENSIONS
± $\frac{1}{64}$ ON FRACTIONAL DIMENSIONS
±1° ON ANGULAR DIMENSIONS

DRAWN BY: E.F.S.	ARBOR PRESS BASE	
SCALE: ——		DWG. NO. 33

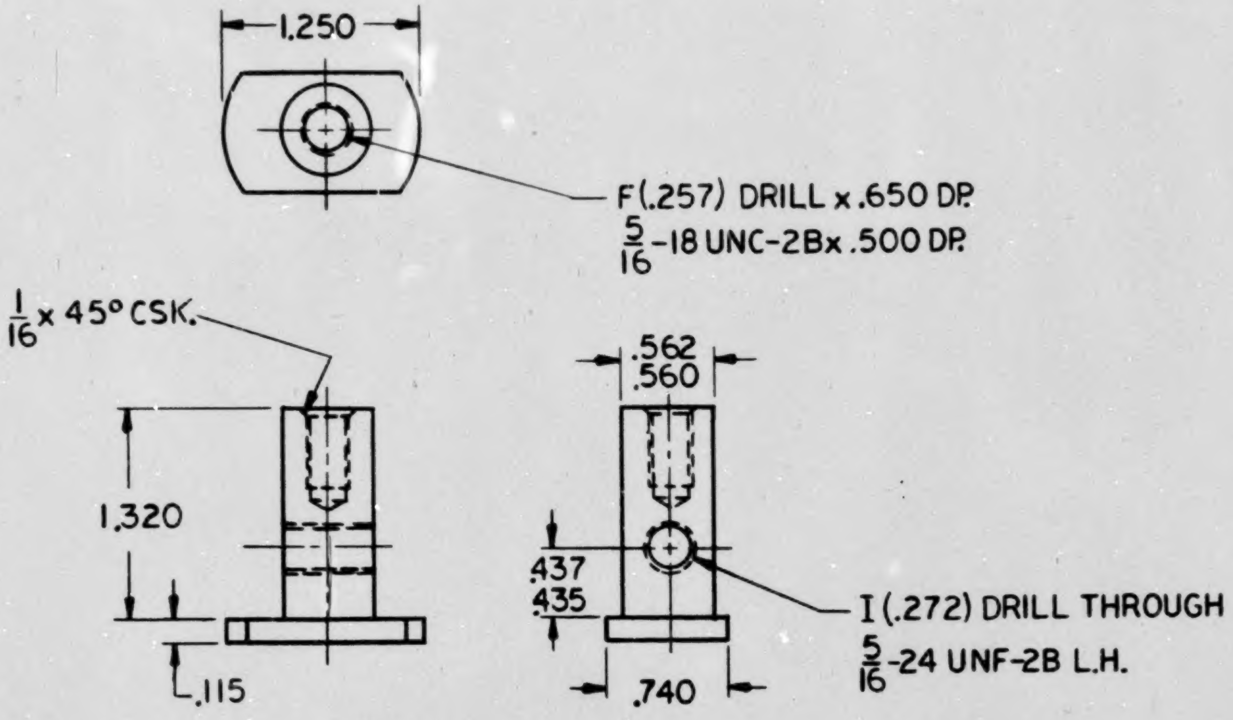

A
A
$\frac{5}{16}$-18 UNC-2A x $\frac{5}{8}$ LG.
CAP SCREW
$\frac{1}{4}$-20 UNC-2A x $\frac{1}{2}$ LG.
SET SCREW
LEAD SCREW
END NUT
LEAD SCREW NUT

SECTION A-A

DRAWN BY: E.F.S.
SCALE: ——

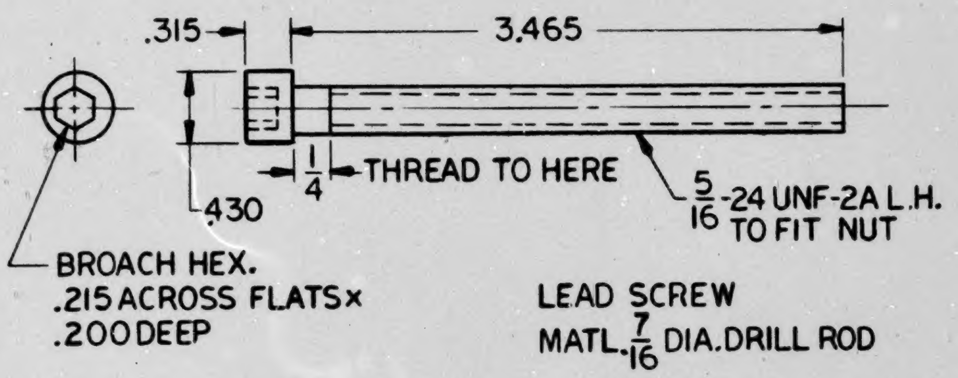
GRINDING VISE ASSEMBLY

DWG. NO. 36


1.250
F(.257) DRILL x .650 DP.
5/16-18 UNC-2B x .500 DP.
1/16 x 45° CSK.
1.320
.115
.562
.560
.437
.435
.740
I (.272) DRILL THROUGH
5/16-24 UNF-2B L.H.

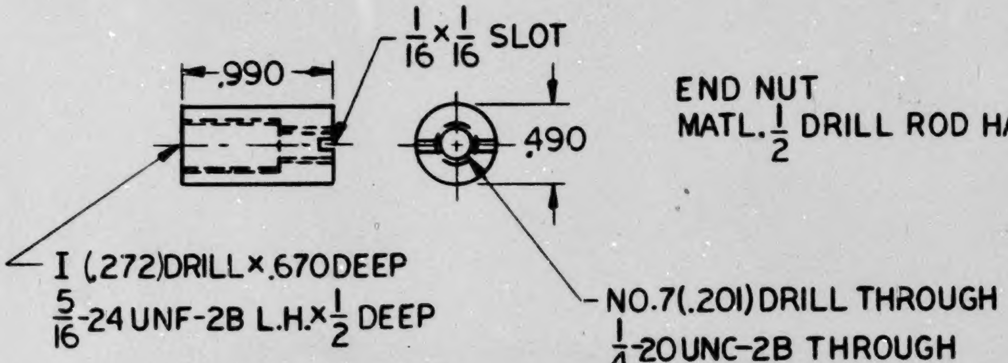
TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
±.005 ON DECIMAL DIMENSIONS
± $\frac{1}{64}$ ON FRACTIONAL DIMENSIONS
±1° ON ANGULAR DIMENSIONS

DRAWN BY: E.F.S.	GRINDING VISE LEAD SCREW NUT	
SCALE : ——		DWG. NO. 37


.315
3.465
.430
$\frac{1}{4}$
THREAD TO HERE
$\frac{5}{16}$-24 UNF-2A L.H. TO FIT NUT
BROACH HEX. .215 ACROSS FLATS × .200 DEEP

LEAD SCREW
MATL. $\frac{7}{16}$ DIA. DRILL ROD

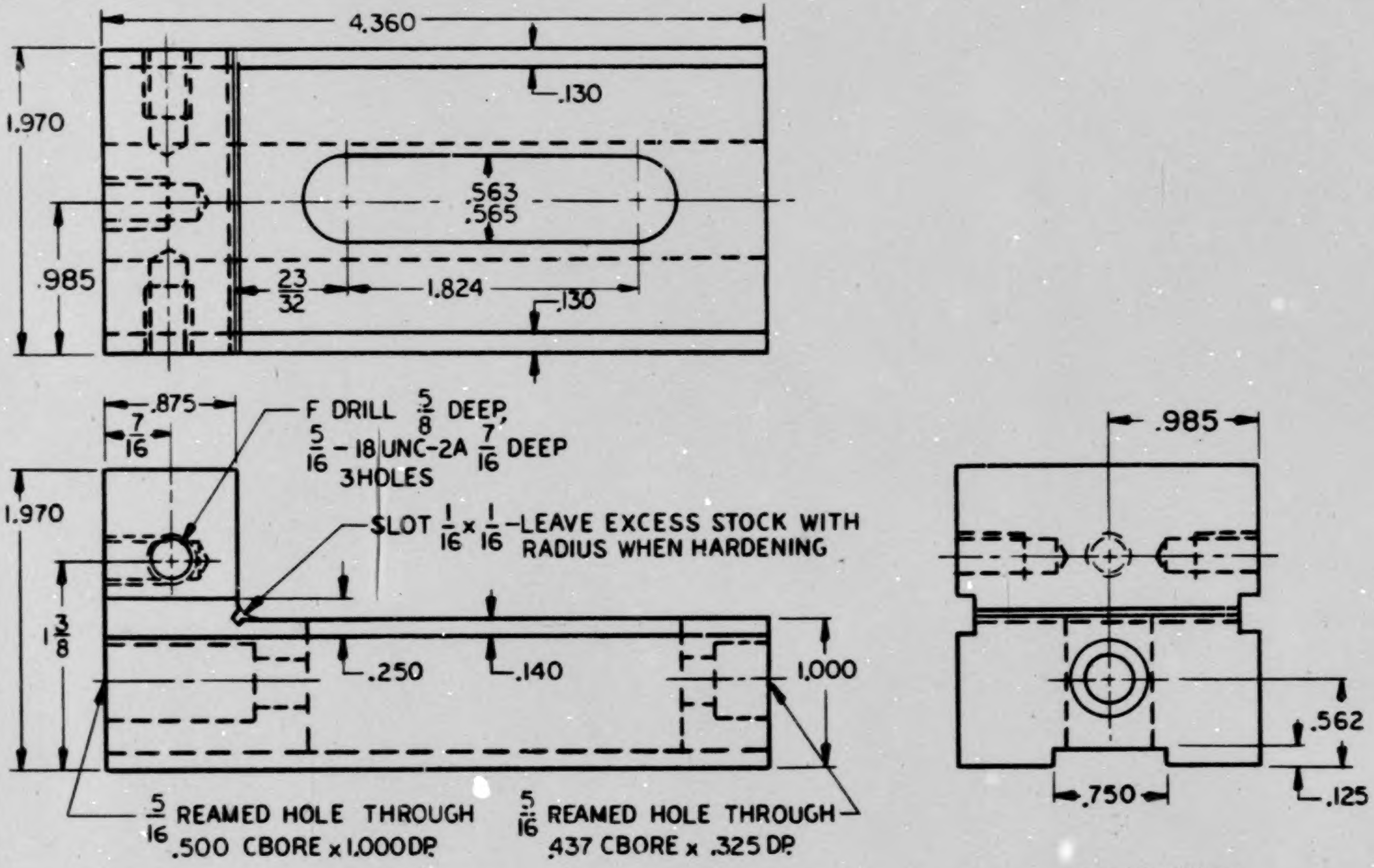
ADDITIONAL PARTS
SET SCREW $\frac{1}{4}$-20 UNC-2A × $\frac{1}{2}$ LG.
CAP SCREW $\frac{5}{16}$-18 UNC-2A × $\frac{5}{8}$ LG.


.990
$\frac{1}{16}$ × $\frac{1}{16}$ SLOT
.490
I (.272) DRILL × .670 DEEP
$\frac{5}{16}$-24 UNF-2B L.H. × $\frac{1}{2}$ DEEP
NO.7 (.201) DRILL THROUGH
$\frac{1}{4}$-20 UNC-2B THROUGH

END NUT
MATL. $\frac{1}{2}$ DRILL ROD HARDENED

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
±.005 ON DECIMAL DIMENSIONS
± $\frac{1}{64}$ ON FRACTIONAL DIMENSIONS
±1° ON ANGULAR DIMENSIONS

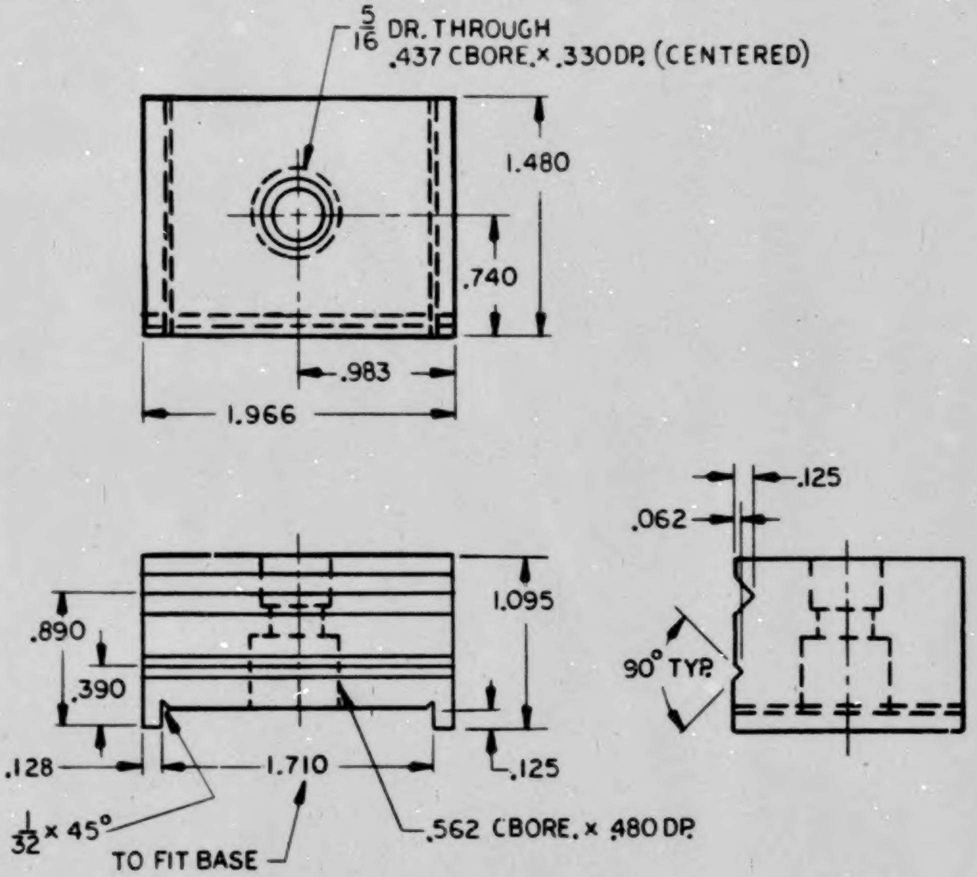
DRAWN BY: E.F.S.	GRINDING VISE LEAD SCREW AND END NUT	
SCALE: ——		DWG. NO. 38


4.360
1.970
.130
.563
.565
.985
23/32
1.824
.130
.875
7/16
F DRILL 5/8 DEEP,
5/16 - 18 UNC-2A 7/16 DEEP
3 HOLES
1.970
SLOT 1/16 x 1/16 - LEAVE EXCESS STOCK WITH RADIUS WHEN HARDENING
1 3/8
.250
.140
1.000
5/16 REAMED HOLE THROUGH .500 CBORE x 1.000 DP.
5/16 REAMED HOLE THROUGH .437 CBORE x .325 DP.
.985
.562
.750
.125

MATL. SAE 1020
CASE HARDEN.

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
± .005 DECIMAL
± $\frac{1}{64}$ FRACTIONAL
± $\frac{1}{2}$° ANGULAR

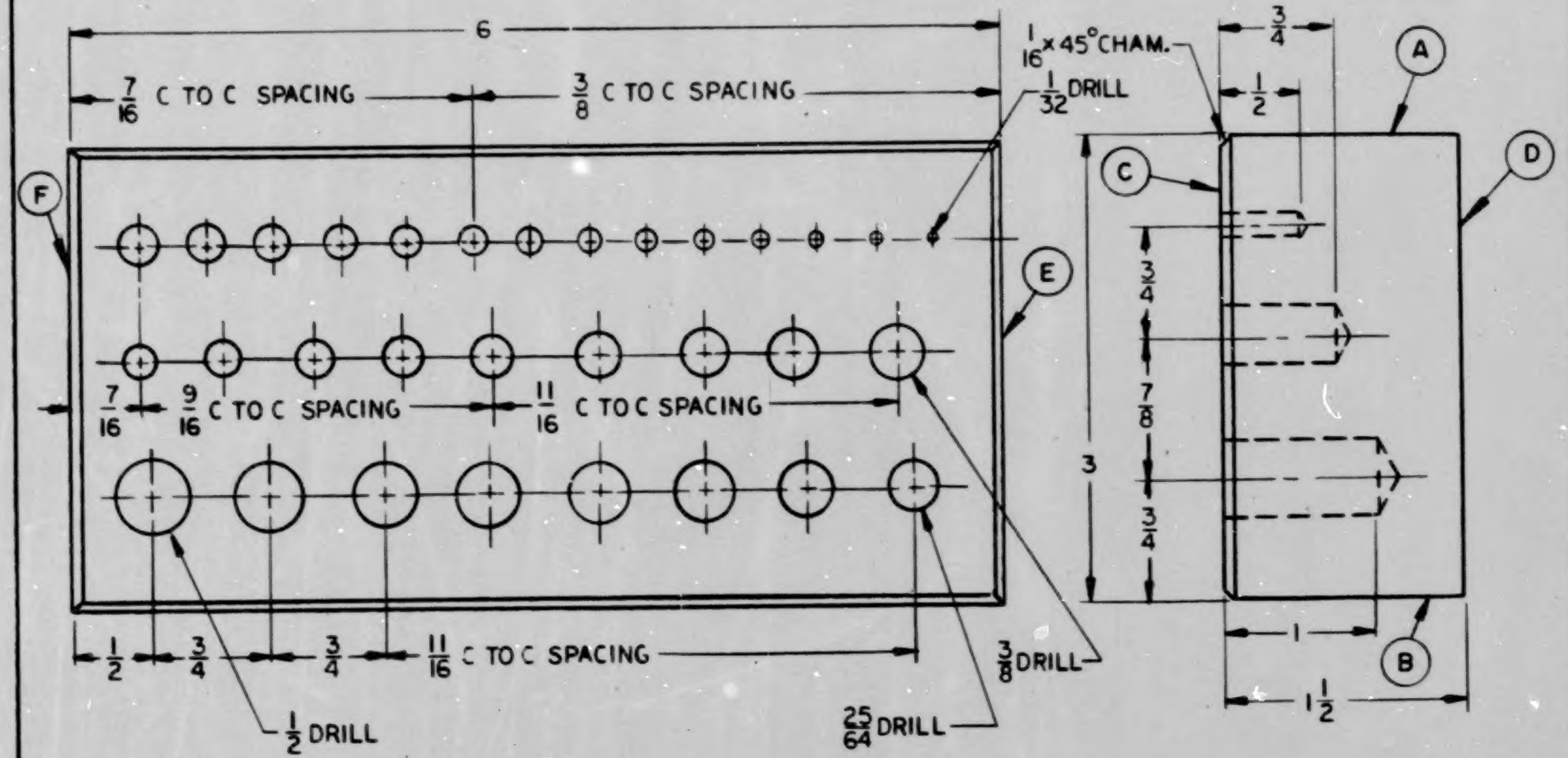
DRAWN BY: E.F.S.	GRINDING VISE BASE	
SCALE: ——		DWG. NO. 39


5/16 DR. THROUGH
.437 CBORE. × .330 DP. (CENTERED)
1.480
.740
.983
1.966
.125
.062
90° TYP.
1.095
.890
.390
.128
1.710
.125
1/32 × 45°
TO FIT BASE
.562 CBORE. × .480 DP.

MATL. SAE 1020
CASE HARDEN.

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
±.005 DECIMAL
±1/64 FRACTIONAL
±1/2° ANGULAR

DRAWN BY: E.F.S.	GRINDING VISE SLIDING JAW	
SCALE: ——		DWG. NO. 40


6
$\frac{7}{16}$ C TO C SPACING
$\frac{3}{8}$ C TO C SPACING
$\frac{1}{16}$ x 45° CHAM.
$\frac{1}{32}$ DRILL
$\frac{3}{4}$
$\frac{1}{2}$
A
B
C
D
E
F
$\frac{7}{16}$
$\frac{9}{16}$ C TO C SPACING
$\frac{11}{16}$ C TO C SPACING
3
$\frac{3}{4}$
$\frac{7}{8}$
$\frac{3}{4}$
1
$1\frac{1}{2}$
$\frac{1}{2}$
$\frac{3}{4}$
$\frac{3}{4}$
$\frac{11}{16}$ C TO C SPACING
$\frac{3}{8}$ DRILL
$\frac{1}{2}$ DRILL
$\frac{25}{64}$ DRILL

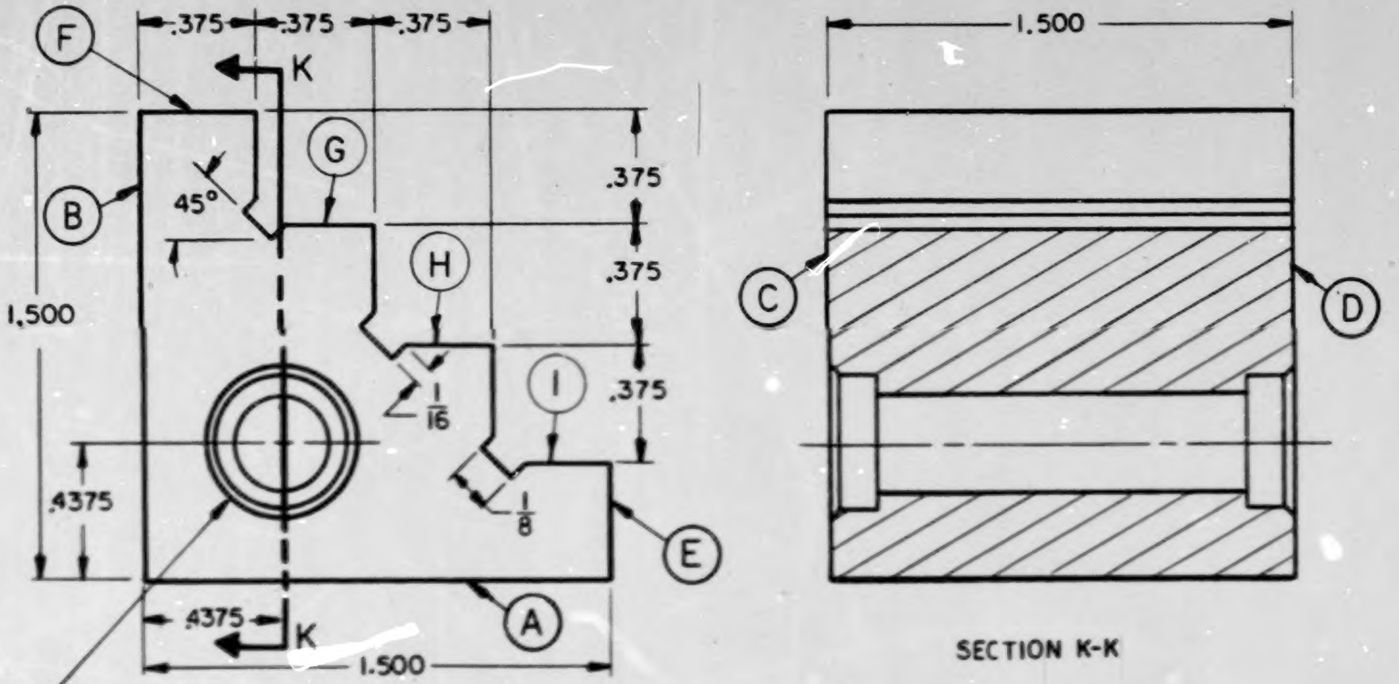
NOTES:
MATL. CAST ALUM.
HOLES GO FROM $\frac{1}{32}$ TO $\frac{1}{2}$ BY 64 ths
FAO

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
± .005 DECIMAL
± $\frac{1}{64}$ FRACTIONAL
± $\frac{1}{2}$° ANGULAR

DRAWN BY: E.F.S.
SCALE: ——

DRILL STAND

DWG. NO. 42


F
B
G
H
I
E
A
C
D
K
K
.375
.375
.375
.375
.375
.375
45°
1.500
.4375
.4375
1.500
$\frac{1}{16}$
$\frac{1}{8}$
1.500
SECTION K-K

$\frac{5}{16}$ DR. THROUGH, $\frac{7}{16}$ CBORE x $\frac{5}{16}$ DP. &
CSINK. $\frac{1}{16}$ DP. BOTH SIDES.

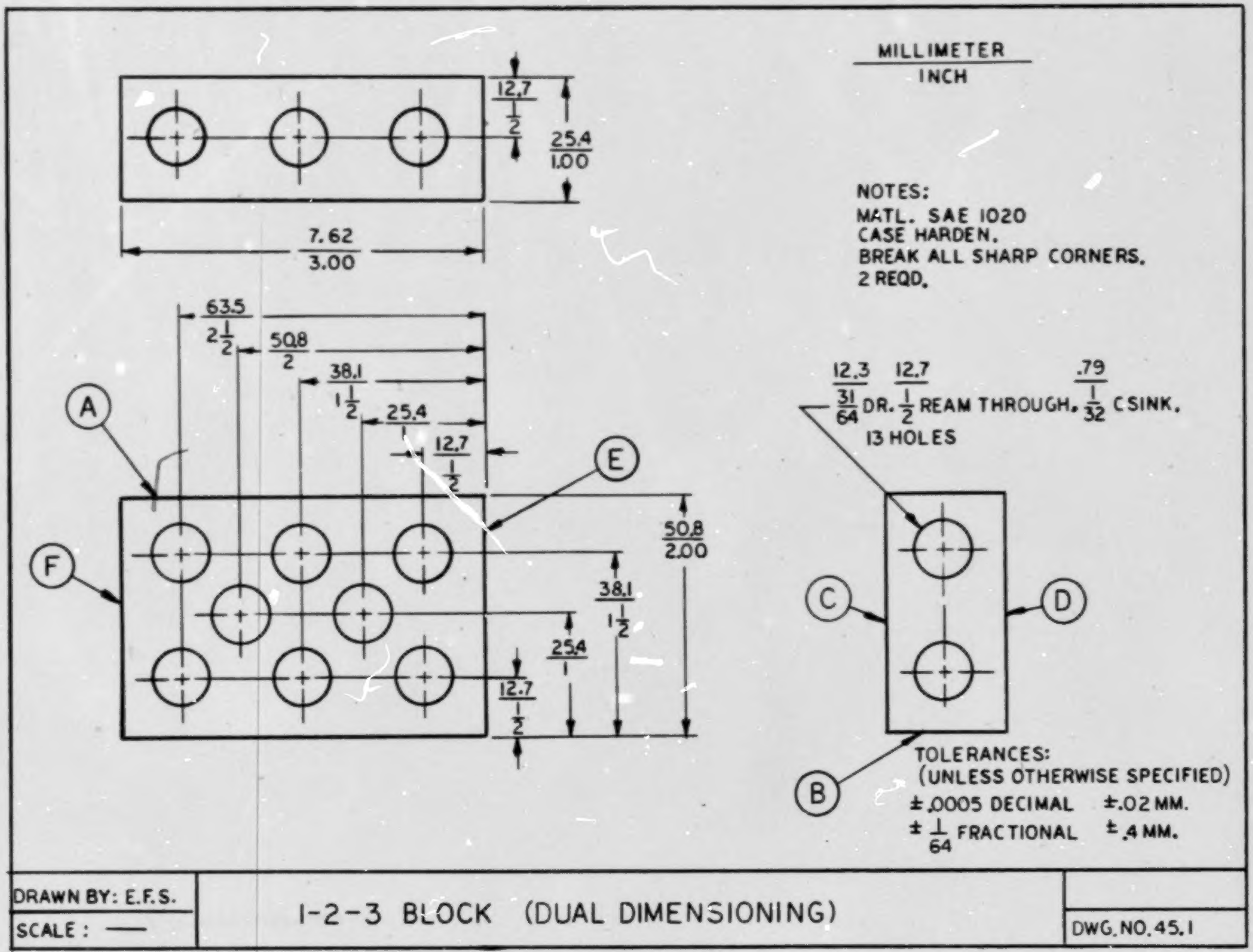
NOTES:
MATL. TOOL STEEL
GRIND ALL FLAT SURFACES.
LEAVE .015 ON EACH SURFACE FOR GRINDING.
HEAT TREAT TO 60C ROCKWELL.

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
± .0005 DECIMAL
± $\frac{1}{64}$ FRACTIONAL
± $\frac{1}{2}$° ANGULAR

DRAWN BY: E.F.S.
SCALE: ——

PRECISION STEP BLOCK

DWG. NO. 44


12.7
1/2
25.4
1.00
7.62
3.00
63.5
2 1/2
50.8
2
38.1
1 1/2
25.4
1
12.7
1/2
50.8
2.00
38.1
1 1/2
25.4
1
12.7
1/2
A
B
C
D
E
F

MILLIMETER
INCH

NOTES:
MATL. SAE 1020
CASE HARDEN.
BREAK ALL SHARP CORNERS.
2 REQD.

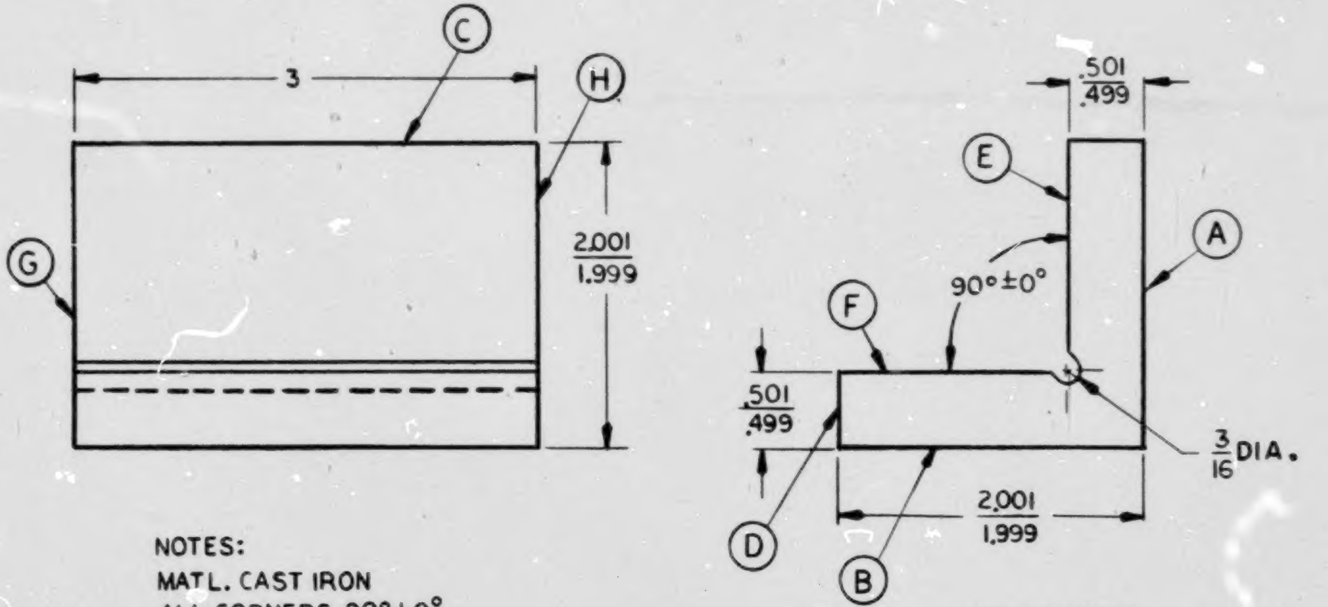
$\frac{12.3}{\frac{31}{64}}$ DR. $\frac{12.7}{\frac{1}{2}}$ REAM THROUGH, $\frac{.79}{\frac{1}{32}}$ CSINK.
13 HOLES

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
±.0005 DECIMAL ±.02 MM.
± $\frac{1}{64}$ FRACTIONAL ±.4 MM.

DRAWN BY: E.F.S.
SCALE : —

1-2-3 BLOCK (DUAL DIMENSIONING)

DWG. NO. 45.1



3
Ⓒ
Ⓗ
Ⓖ
2.001/1.999
.501/.499
Ⓔ
Ⓐ
90°±0°
Ⓕ
.501/.499
3/16 DIA.
2.001/1.999
Ⓓ
Ⓑ

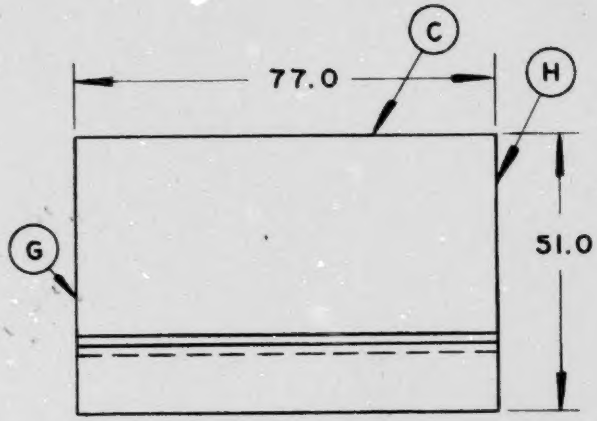
NOTES:
MATL. CAST IRON
ALL CORNERS 90°±0°

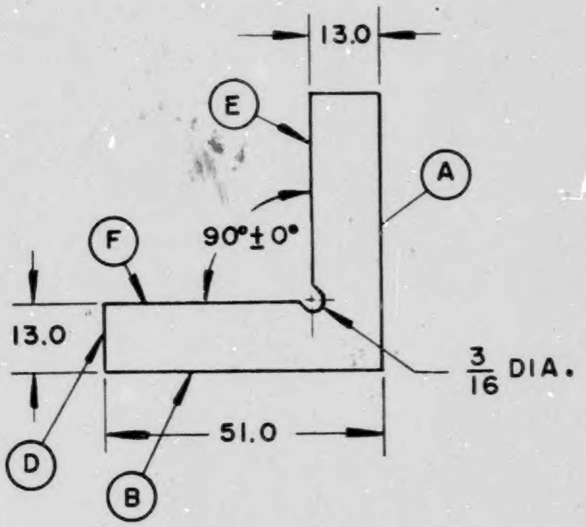
TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
±.005 DECIMAL
± $\frac{1}{64}$ FRACTIONAL
± $\frac{1}{2}$° ANGULAR

DRAWN BY: E.F.S.
SCALE: —

PRECISION ANGLE PLATE (INCHES)

DWG.NO. 46 A

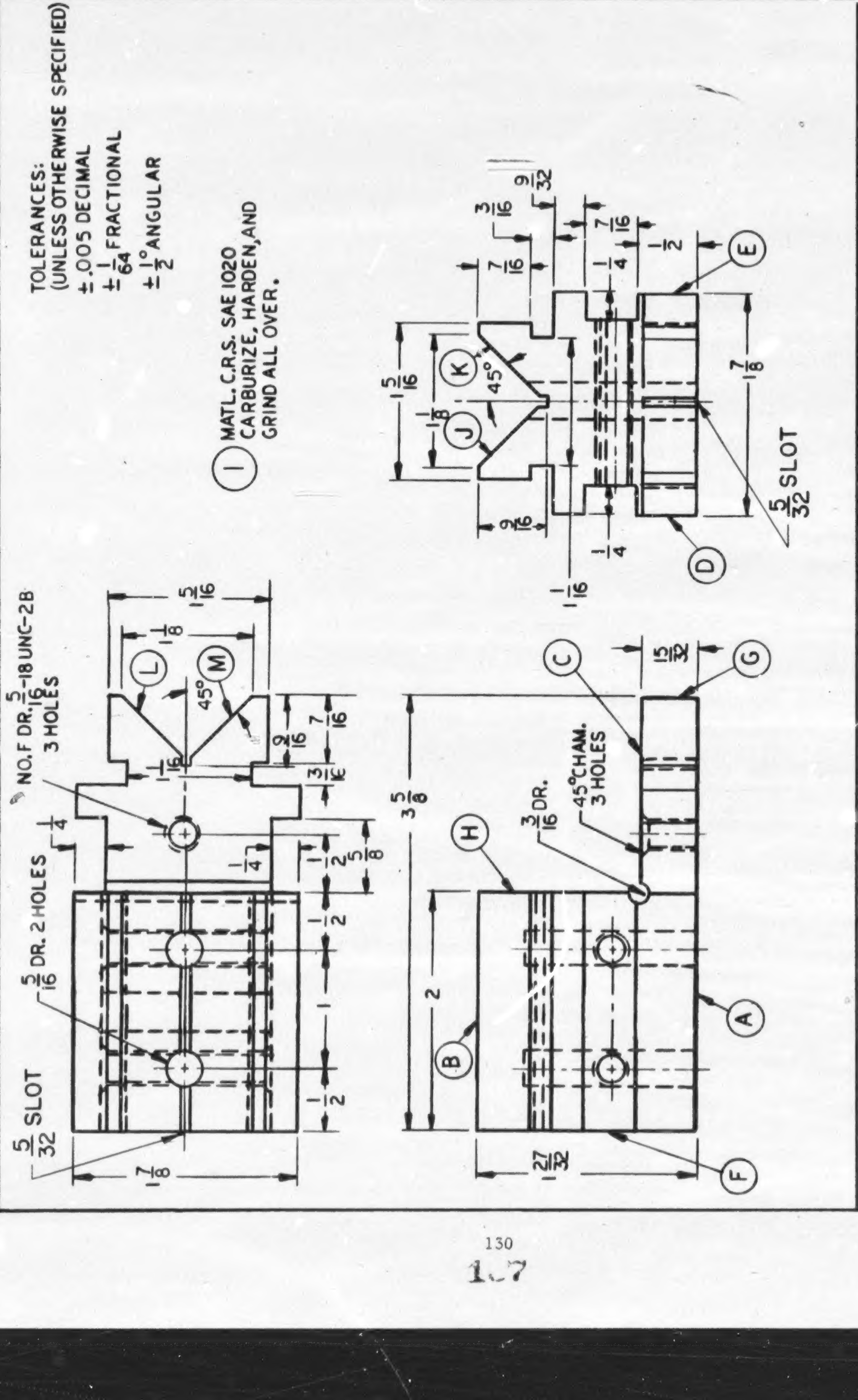



13.0
E
A
90°±0°
F
13.0
3/16 DIA.
51.0
D
B

NOTES:
MATERIAL: CAST IRON
ALL CORNERS 90° ± 0°

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
±0.40 MILLIMETERS

DRAWN BY: V.C.L.	PRECISION ANGLE PLATE (MILLIMETERS)	
SCALE: —		DWG.NO. 46B



NO. F DR. 5/16-18 UNC-2B 3 HOLES
5/16 DR. 2 HOLES
5/32 SLOT
1 7/8
1/2
1
1/2
1/4
1/4
1/2
5/8
3/16
9/16
7/16
1 1/16
45°
L
M
1 1/8
1 5/16
3 5/8
2
1 27/32
3/16 DR.
45° CHAM. 3 HOLES
15/32
H
C
G
B
A
F
1 5/16
1 1/8
45°
J
K
7/16
3/16
9/32
7/16
1/4
1/2
9/16
1/4
1 1/16
1 7/8
5/32 SLOT
D
E

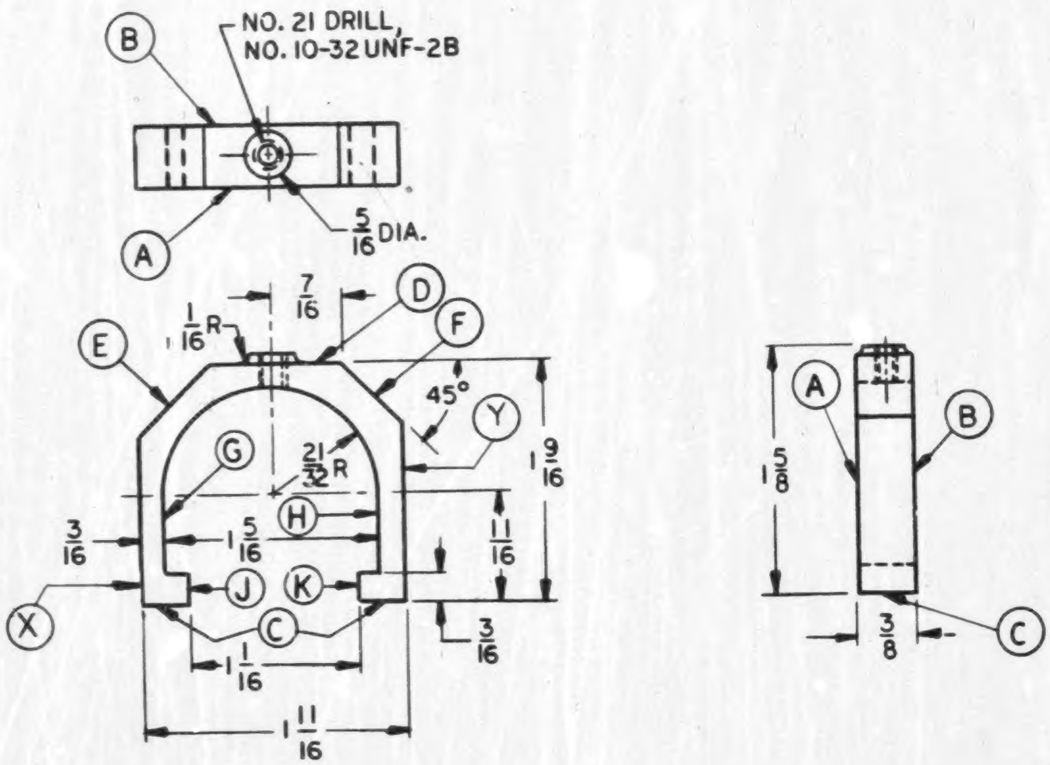
TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
± .005 DECIMAL
± 1/64 FRACTIONAL
± 1/2° ANGULAR

① MATL. C.R.S. SAE 1020
CARBURIZE, HARDEN, AND
GRIND ALL OVER.

DRAWN BY: E.F.S.
SCALE: ——

V-BLOCK

DWG. NO. 47


NO. 21 DRILL,
NO. 10-32 UNF-2B
B
A
$\frac{5}{16}$ DIA.
$\frac{7}{16}$
$\frac{1}{16}$R
D
E
F
45°
Y
G
$\frac{21}{32}$R
$1\frac{9}{16}$
H
$\frac{3}{16}$
$1\frac{5}{16}$
$\frac{11}{16}$
X
J
K
C
$\frac{3}{16}$
$1\frac{1}{16}$
$1\frac{11}{16}$
A
B
$1\frac{5}{8}$
$\frac{3}{8}$
C

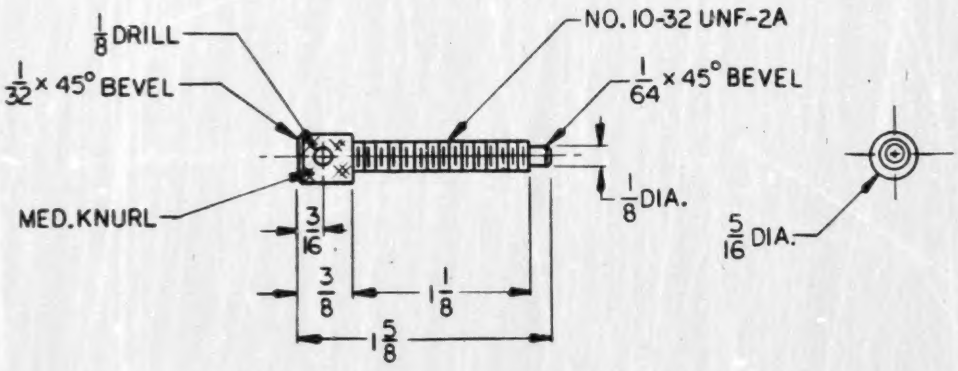
MATL. SAE 1020
FAO

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
±.005 DECIMAL
$\pm\frac{1}{64}$ FRACTIONAL
$\pm\frac{1}{2}$° ANGULAR

DRAWN BY: E.F.S.
SCALE: ——

V-BLOCK
CLAMP

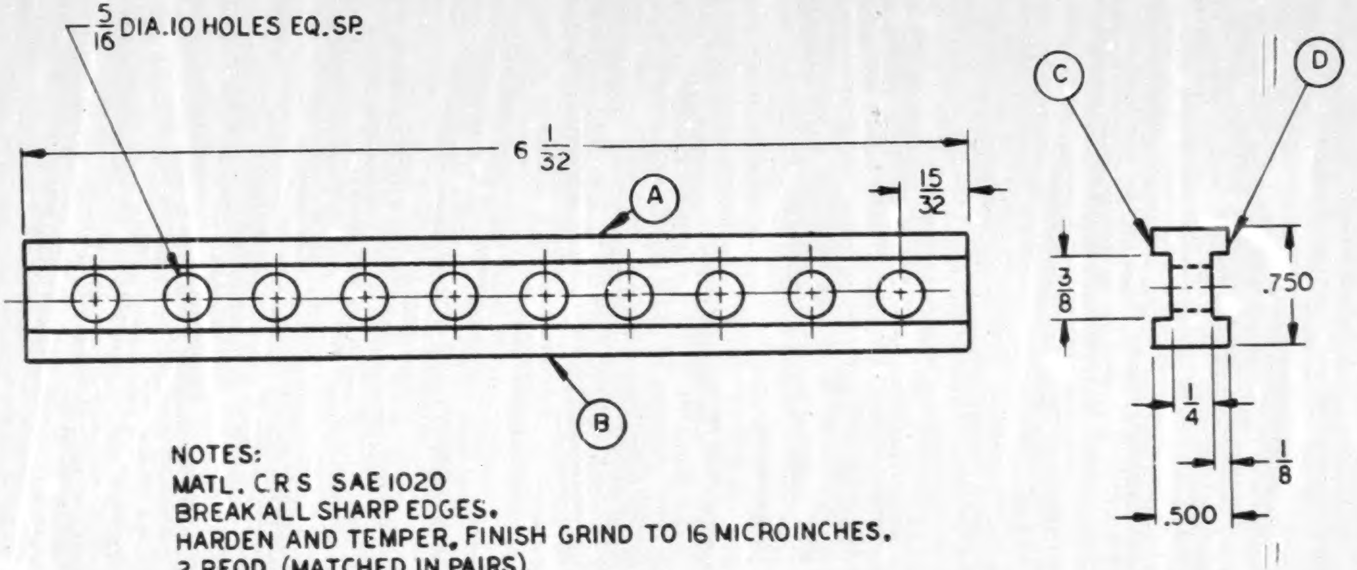
DWG. NO. 48


$\frac{1}{8}$ DRILL
$\frac{1}{32}$ × 45° BEVEL
MED. KNURL
NO. 10-32 UNF-2A
$\frac{1}{64}$ × 45° BEVEL
$\frac{1}{8}$ DIA.
$\frac{5}{16}$ DIA.
$\frac{3}{16}$
$\frac{3}{8}$
$1\frac{1}{8}$
$1\frac{5}{8}$

MATL. SAE 1020

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
± .005 DECIMAL
± $\frac{1}{64}$ FRACTIONAL
± $\frac{1}{2}$° ANGULAR

DRAWN BY: E.F.S.	V-BLOCK CLAMP SCREW	
SCALE: ——		DWG. NO. 49


$\frac{5}{16}$ DIA. 10 HOLES EQ. SP.
$6\frac{1}{32}$
$\frac{15}{32}$
A
B
C
D
$\frac{3}{8}$
.750
$\frac{1}{4}$
$\frac{1}{8}$
.500

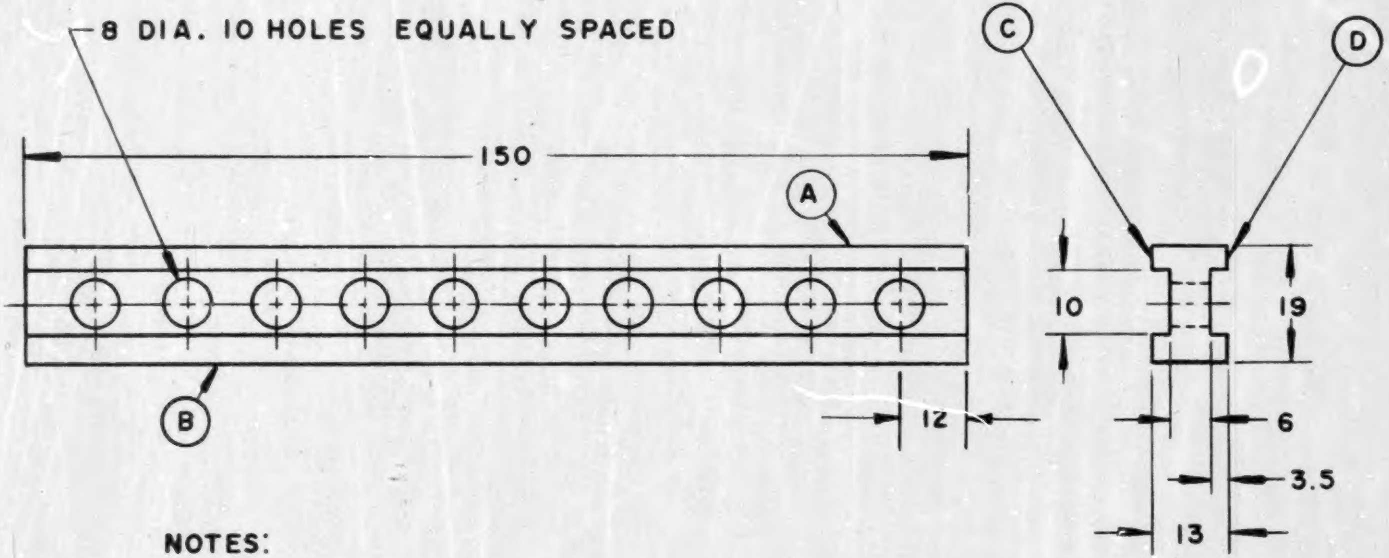
NOTES:
MATL. C R S SAE 1020
BREAK ALL SHARP EDGES.
HARDEN AND TEMPER, FINISH GRIND TO 16 MICROINCHES.
2 REQD. (MATCHED IN PAIRS)
LEAVE .030 FOR GRINDING ON .500 AND
.750 DIMENSIONS.

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
±.005 DECIMAL
$\pm\frac{1}{64}$ FRACTIONAL
$\pm\frac{1}{2}^{\circ}$ ANGULAR

DRAWN BY: E.F.S.
SCALE: ——

PARALLELS (INCHES)

DWG. NO. 50 A


8 DIA. 10 HOLES EQUALLY SPACED
150
A
B
C
D
10
19
12
6
3.5
13

NOTES:

MATL. CRS SAE 1020

BREAK ALL SHARP EDGES.

HARDEN AND TEMPER, FINISH GRIND TO 16 MICROINCHES.

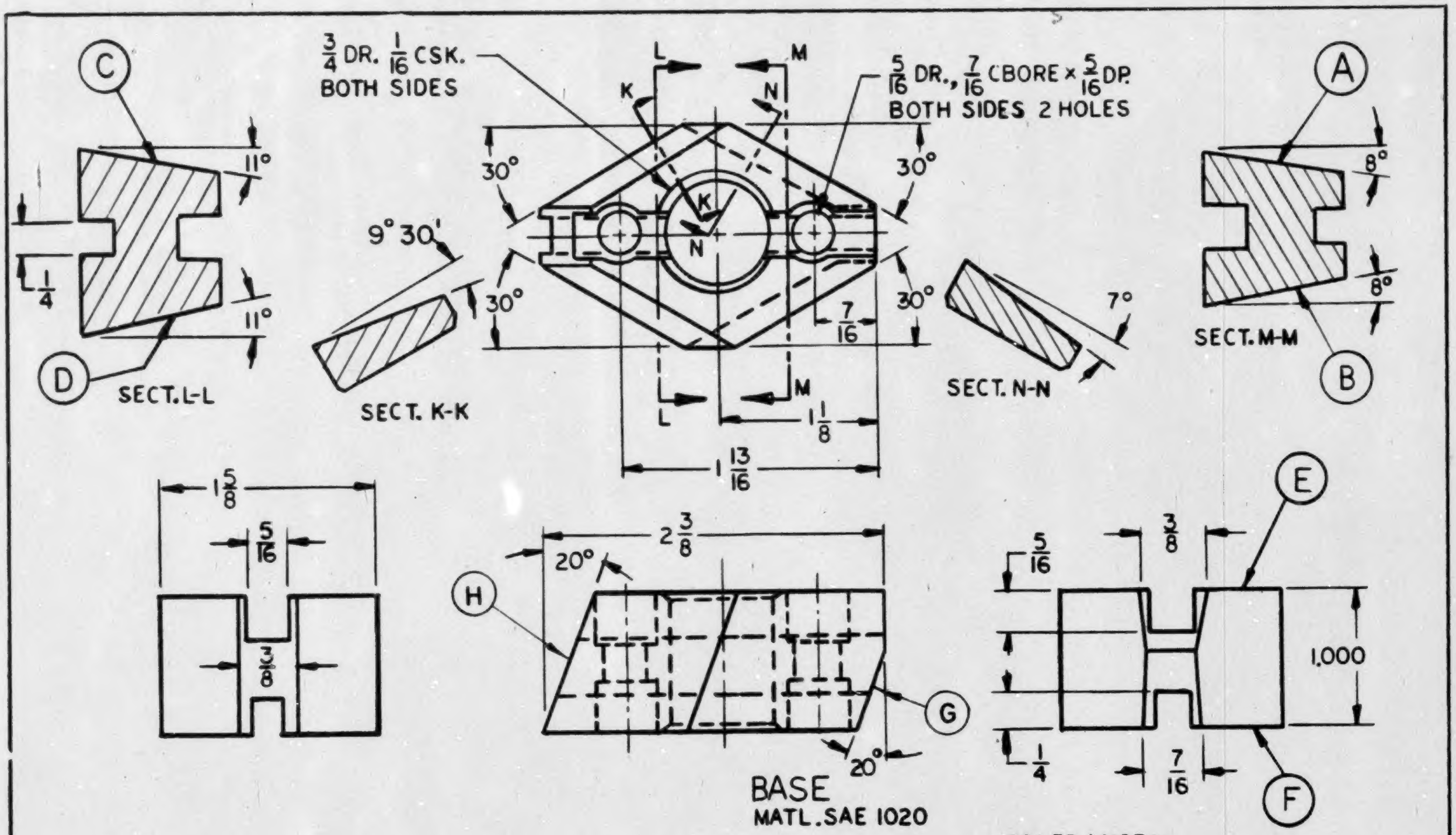
2 REQD. (MATCHED IN PAIRS)

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
± 0.4 MILLIMETER

DRAWN BY: V.C.L.
SCALE: ——

PARALLELS (MILLIMETERS)

DWG.NO. 50 B

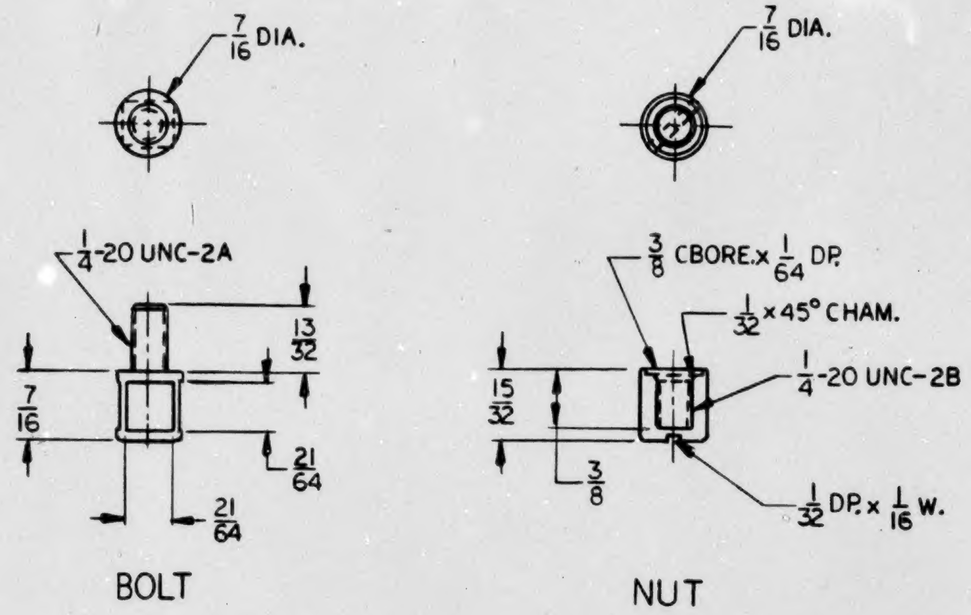

$\frac{3}{4}$ DR. $\frac{1}{16}$ CSK.
BOTH SIDES
$\frac{5}{16}$ DR., $\frac{7}{16}$ CBORE × $\frac{5}{16}$ DP.
BOTH SIDES 2 HOLES
A
B
C
D
E
F
G
H
K
L
M
N
11°
8°
30°
9° 30'
7°
20°
$\frac{1}{4}$
$\frac{7}{16}$
$1\frac{1}{8}$
$1\frac{13}{16}$
$1\frac{5}{8}$
$\frac{5}{16}$
$\frac{3}{8}$
$2\frac{3}{8}$
1.000
SECT. L-L
SECT. K-K
SECT. N-N
SECT. M-M
BASE
MATL. SAE 1020

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
±.005 DECIMAL
± $\frac{1}{64}$ FRACTIONAL
± 0° ANGULAR

DRAWN BY: E.F.S.
SCALE: ——

GRINDING FIXTURE FOR THREAD TOOL
BASE

DWG. NO. 54

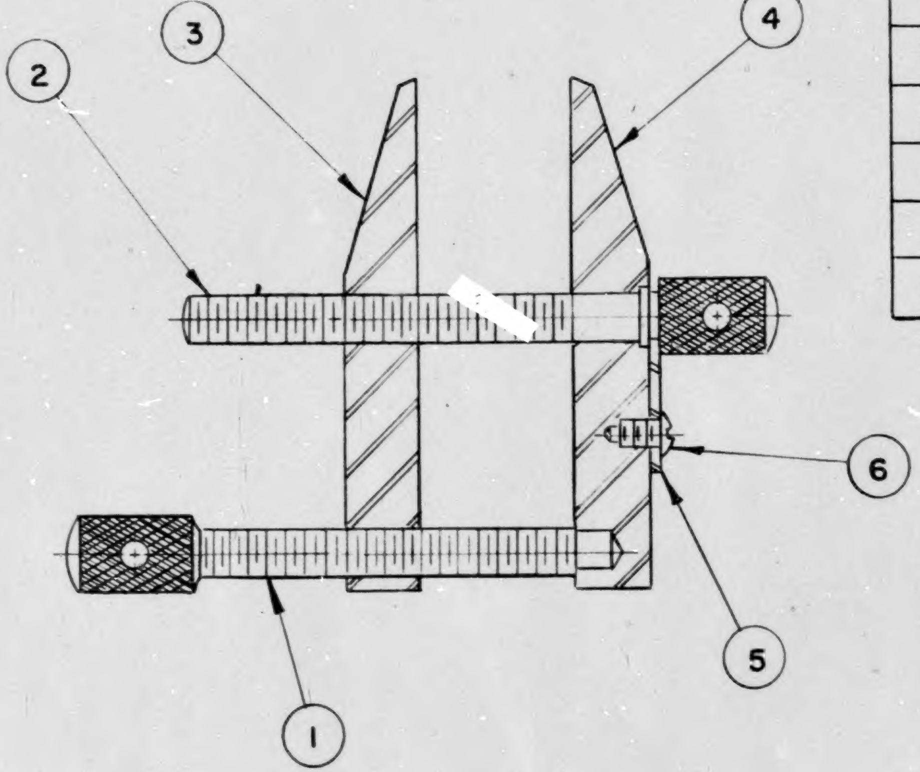


$\frac{7}{16}$ DIA.
$\frac{7}{16}$ DIA.
$\frac{1}{4}$-20 UNC-2A
$\frac{13}{32}$
$\frac{7}{16}$
$\frac{21}{64}$
$\frac{21}{64}$
BOLT
$\frac{3}{8}$ CBORE.x $\frac{1}{64}$ DP.
$\frac{1}{32}$ x 45° CHAM.
$\frac{1}{4}$-20 UNC-2B
$\frac{15}{32}$
$\frac{3}{8}$
$\frac{1}{32}$ DP. x $\frac{1}{16}$ W.
NUT

MATL. SAE 1020

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
±.005 DECIMAL
± $\frac{1}{64}$ FRACTIONAL
± $\frac{1}{2}$° ANGULAR

DRAWN BY: E.F.S.	GRINDING FIXTURE FOR THREAD TOOL NUT AND BOLT	
SCALE: —		DWG. NO. 55



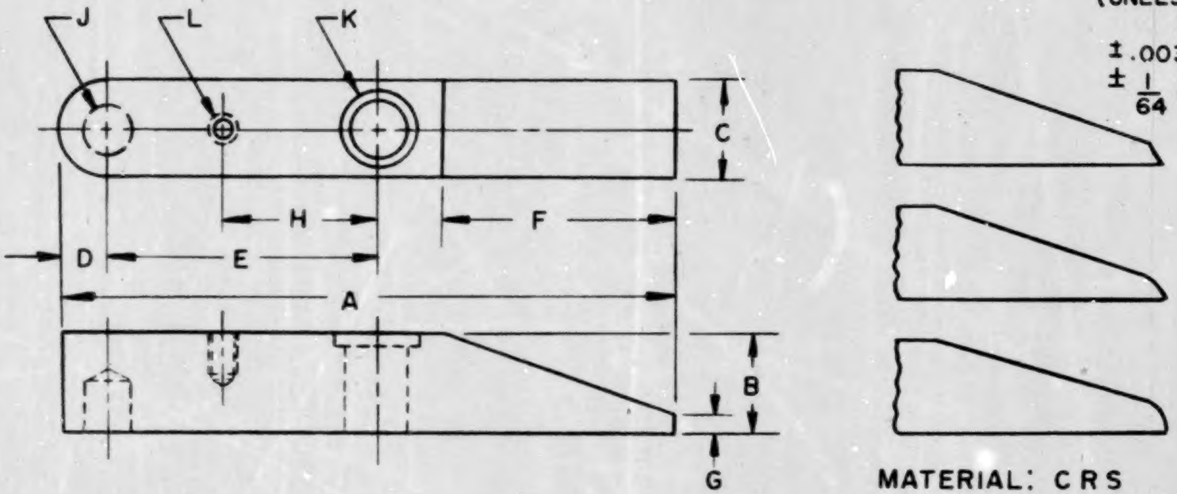
ITEM	PART NAME	MATL.
1	CLAMPING SCR	CRS
2	ADJUSTING SCR.	CRS
3	THREADED JAW	CRS
4	LOOSE JAW	CRS
5	STRAIGHT CLIP	CRS
6	RD. HD. MACH. SCR 8-32 X $\frac{1}{4}$	COMM.

DRAWN BY: V.C.L.

PARALLEL CLAMP
ASSEMBLY

DWG. NO. 56

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
±.003 DECIMAL
± $\frac{1}{64}$ FRACTIONAL



MATERIAL: CRS
CASE HARDEN

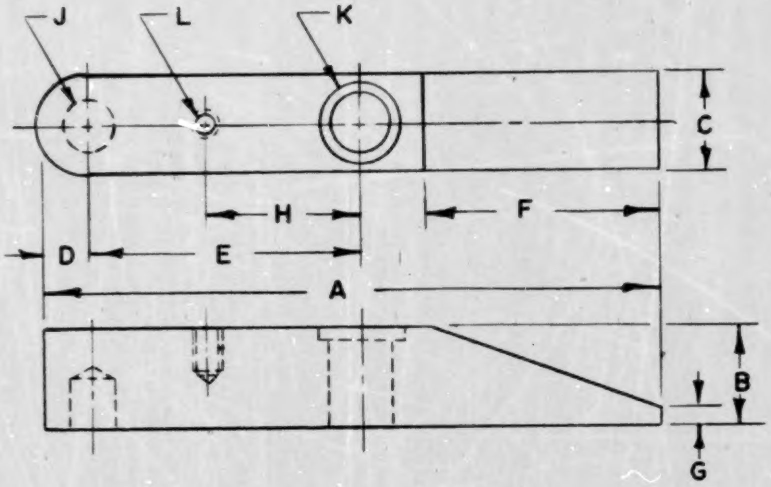
REF. NO.	FINISHED DIMENSIONS (INCHES)										
	A	B	C	D	E	F	G	H	J	K, CBORE.	L
1	$2\frac{1}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{32}$	1	$\frac{3}{4}$	$\frac{1}{16}$	$\frac{1}{2}$	$\frac{1}{8}$ DIA x $\frac{5}{32}$ DEEP	$\frac{7}{32}$ DIA. $\frac{1}{4}$ x $\frac{3}{32}$ DEEP	6-32 UNC x $\frac{3}{16}$ DP.
2	$2\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{16}$	$1\frac{1}{4}$	1	$\frac{3}{32}$	$\frac{3}{4}$	$\frac{3}{16}$ DIA x $\frac{3}{16}$ DEEP	$\frac{9}{32}$ DIA. $\frac{5}{16}$ x $\frac{3}{32}$ DEEP	6-32 UNC x $\frac{3}{16}$ DP.
3	$3\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{1}{8}$	$\frac{3}{4}$	$\frac{1}{4}$ DIA x $\frac{1}{4}$ DEEP	$\frac{11}{32}$ DIA. $\frac{7}{16}$ x $\frac{3}{32}$ DEEP	8-32 UNC x $\frac{5}{16}$ DP.
4	4	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{16}$	$1\frac{3}{4}$	$1\frac{1}{2}$	$\frac{5}{32}$	1	$\frac{5}{16}$ DIA x $\frac{5}{16}$ DEEP	$\frac{13}{32}$ DIA. $\frac{9}{16}$ x $\frac{3}{32}$ DEEP	8-32 UNC x $\frac{5}{16}$ DP.
5	5	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{8}$	$2\frac{3}{8}$	$1\frac{3}{4}$	$\frac{3}{16}$	1	$\frac{3}{8}$ DIA x $\frac{3}{8}$ DEEP	$\frac{17}{32}$ DIA. $\frac{11}{16}$ x $\frac{3}{32}$ DEEP	8-32 UNC x $\frac{5}{16}$ DP.

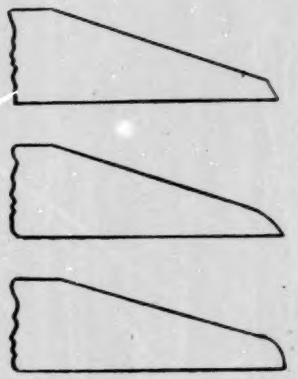
DRAWN BY: V.C.L.

PARALLEL CLAMP
LOOSE JAW (INCHES)

DWG. NO. 57 A

MATERIAL: CRS
CASE HARDEN





ALTERNATE JAW DESIGNS

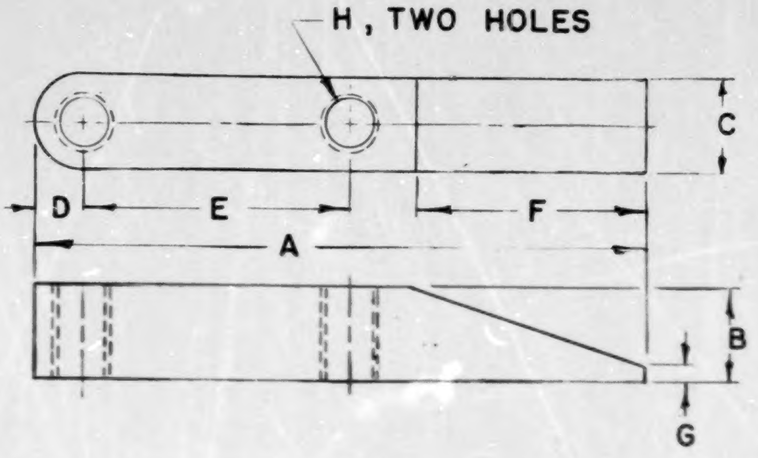
REF.NO.	FINISHED DIMENSIONS											
	MILLIMETERS											INCHES
	A	B	C	D	E	F	G	H	J	K,	CBORE.	L
1	54	8	8	4.0	25.4	19.1	1.6	12.7	3.18D. X 3.97 DP.	5.56D.	6.35 X 2.38DP.	6-32 UNC x $\frac{3}{16}$ DP.
2	69.9	9.5	9.6	4.8	31.8	25.4	2.4	19.1	4.76D. X 4.76 DP.	7.15D.	7.94 X 2.38DP.	6-32 UNC x $\frac{3}{16}$ DP.
3	85.7	13	12.8	6.4	38.1	31.8	3.2	19.1	6.35D. X 6.35 DP.	8.73D.	11.11 X 2.38DP.	8-32 UNC x $\frac{5}{16}$ DP.
4	101.6	16	15.8	7.9	44.5	38.1	4.0	25.4	7.94D. X 7.94 DP.	10.32D.	14.29 X 2.38DP.	8-32 UNC x $\frac{5}{16}$ DP.
5	127	19	19	9.5	60.3	44.5	4.8	25.4	9.53D. X 9.53 DP.	13.50D.	17.46 X 2.38DP.	8-32 UNC x $\frac{5}{16}$ DP.

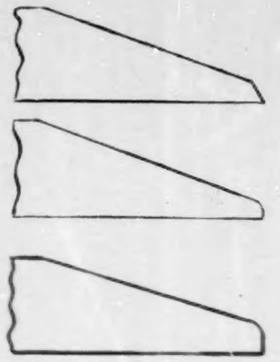
TOLERANCES: UNLESS OTHERWISE SPECIFIED ±0.4MM.
FRACTIONAL: $\pm\frac{1}{64}$

DRAWN BY: V.C.L

PARALLEL CLAMP
LOOSE JAW (MILLIMETERS)

DWG. NO. 57B





ALTERNATE JAW DESIGNS

REF. NO.	FINISHED DIMENSIONS (INCHES)							
	A	B	C	D	E	F	G	H
1	$2\frac{1}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{32}$	1	$\frac{3}{4}$	$\frac{1}{16}$	10-24UNC-2
2	$2\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{16}$	$1\frac{1}{4}$	1	$\frac{3}{32}$	$\frac{1}{4}$-20UNC-2
3	$3\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{1}{8}$	$\frac{5}{16}$-18UNC-2
4	4	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{16}$	$1\frac{3}{4}$	$1\frac{1}{2}$	$\frac{5}{32}$	$\frac{3}{8}$-16UNC-2
5	5	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{8}$	$2\frac{3}{8}$	$1\frac{3}{4}$	$\frac{3}{16}$	$\frac{1}{2}$-13UNC-2

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
± .003 DECIMAL
$\pm \frac{1}{64}$ FRACTIONAL

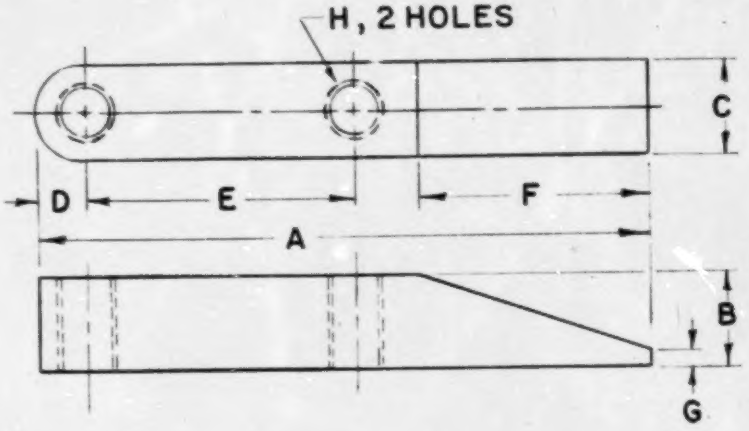
MATERIAL: CRS

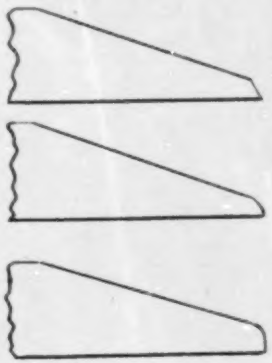
CASE HARDEN

DRAWN BY: V.C.L.

PARALLEL CLAMP
THREADED JAW (INCHES)

DWG. NO. 58A





ALTERNATE JAW DESIGNS

REF. NO.	FINISHED DIMENSIONS							
	MILLIMETERS							INCHES
	A	B	C	D	E	F	G	H
1	54	8.0	8.0	4.0	25.4	19.1	1.6	10-24UNC-2
2	69.9	9.5	9.6	4.8	31.8	25.4	2.4	$\frac{1}{4}$-20UNC-2
3	85.7	13.0	12.8	6.4	38.1	31.8	3.2	$\frac{5}{16}$-18 UNC-2
4	101.6	16.0	15.8	7.9	44.5	38.1	4.0	$\frac{3}{8}$-16 UNC-2
5	127.0	19.0	19.0	9.5	60.3	44.5	4.8	$\frac{1}{2}$-13 UNC-2

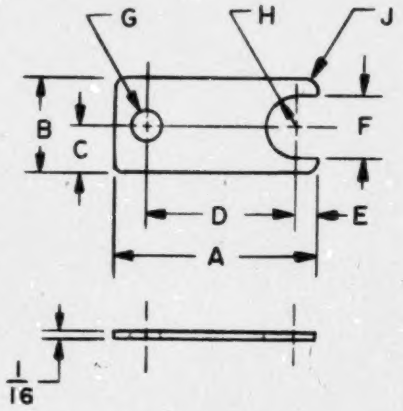
MATERIAL: CRS
CASE HARDEN

TOLERANCES: (UNLESS OTHERWISE SPECIFIED) ± 0.4 MM.

DRAWN BY: V.C.L.

PARALLEL CLAMP
THREADED JAW (MILLIMETERS)

DWG. NO. 58B



NOTES: BREAK ALL SHARP EDGES.
MATERIAL: CRS

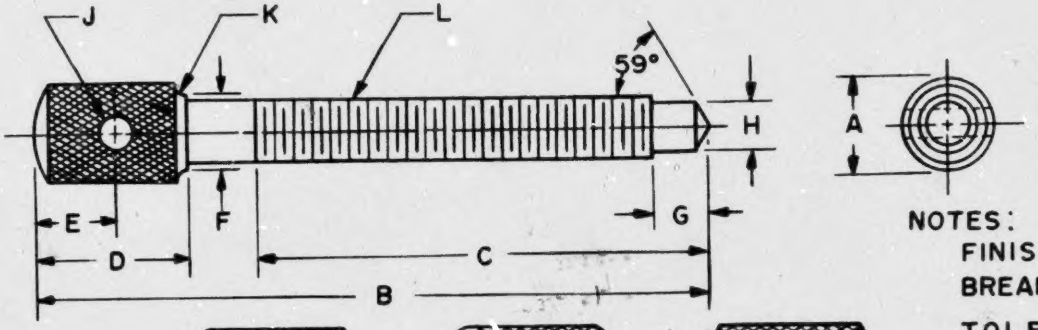
REF. NO.	FINISHED DIMENSIONS (INCHES)								
	A	B	C	D	E	F	G	H	J
1	$\frac{3}{4}$	$\frac{5}{16}$	$\frac{5}{32}$	$\frac{1}{2}$	$\frac{1}{16}$	$\frac{7}{32}$	.149 DIA.	$\frac{7}{64}$ R	$\frac{1}{32}$ R
2	1	$\frac{3}{8}$	$\frac{3}{16}$	$\frac{3}{4}$	$\frac{1}{16}$	$\frac{9}{32}$	.149 DIA.	$\frac{9}{64}$ R	$\frac{1}{32}$ R
3	$1\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{11}{32}$	.177 DIA.	$\frac{11}{64}$ R	$\frac{1}{16}$ R
4	$1\frac{3}{8}$	$\frac{5}{8}$	$\frac{5}{16}$	1	$\frac{1}{8}$	$\frac{13}{32}$	.177 DIA.	$\frac{13}{64}$ R	$\frac{1}{16}$ R
5	$1\frac{3}{8}$	$\frac{3}{4}$	$\frac{3}{8}$	1	$\frac{1}{8}$	$\frac{17}{32}$	.177 DIA.	$\frac{17}{64}$ R	$\frac{1}{16}$ R

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
±.003 DECIMAL
± $\frac{1}{64}$ FRACTIONAL

DRAWN BY: V.C.L.

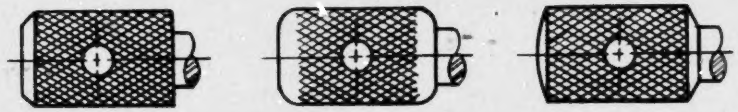
PARALLEL CLAMP
STRAIGHT CLIP

DWG. NO. 59



NOTES:
FINISH ALL OVER.
BREAK SHARP EDGES.

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
FRACTIONAL ± $\frac{1}{64}$
DECIMAL ± .003



ALTERNATE DESIGNS FOR KNURLED END

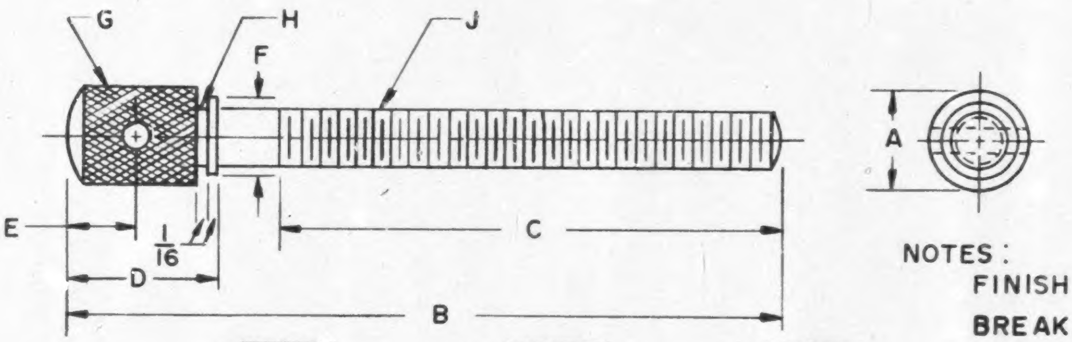
REF. NO.	FINISHED DIMENSIONS (INCHES)											
	A	B	C	D	E	F	G	H	J	K	L	JAW OPENING
1	$\frac{5}{16}$	$2\frac{3}{32}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{5}{32}$	.120	$\frac{1}{8}$	$\frac{1}{32}$ R	10-24UNC-2	1
2	$\frac{3}{8}$	$2\frac{13}{16}$	$1\frac{13}{16}$	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{7}{32}$	.180	$\frac{1}{8}$	$\frac{1}{32}$ R	$\frac{1}{2}$-20UNC-2	$1\frac{1}{2}$
3	$\frac{1}{2}$	$3\frac{5}{8}$	$2\frac{3}{8}$	$\frac{7}{8}$	$\frac{7}{16}$	$\frac{3}{8}$	$\frac{9}{32}$	.240	$\frac{3}{16}$	$\frac{1}{16}$ R	$\frac{5}{16}$-18UNC-2	2
4	$\frac{5}{8}$	$4\frac{7}{16}$	$2\frac{15}{16}$	1	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{11}{32}$	.300	$\frac{3}{16}$	$\frac{1}{16}$ R	$\frac{3}{8}$-16UNC-2	$2\frac{1}{2}$
5	$\frac{3}{4}$	$5\frac{3}{4}$	4	$1\frac{1}{8}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{7}{16}$	.360	$\frac{1}{4}$	$\frac{1}{16}$ R	$\frac{1}{2}$-13UNC-2	$3\frac{1}{2}$

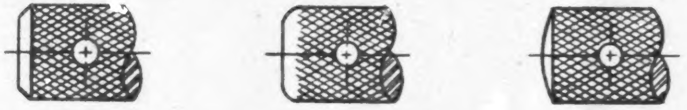
MATERIAL: CRS CASE HARDEN

DRAWN BY: V.C.L.

PARALLEL CLAMP
CLAMPING SCREW

DWG. NO. 60




ALTERNATE DESIGNS FOR KNURLED END

NOTES:
FINISH ALL OVER.
BREAK SHARP EDGES.
TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
FRACTIONAL $\pm \frac{1}{64}$

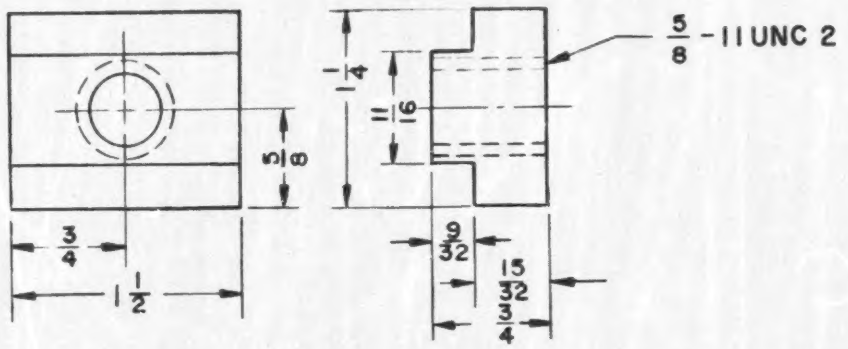
REF. NO.	FINISHED DIMENSIONS (INCHES)									
	A	B	C	D	E	F	G	H	J	JAW OPENING
1	$\frac{5}{16}$	$2\frac{1}{4}$	$1\frac{3}{8}$	$\frac{5}{8}$	$\frac{1}{4}$	$\frac{7}{32}$	$\frac{1}{8}$	$\frac{3}{16}$ DIA.	10-24UNC-2	1
2	$\frac{3}{8}$	3	2	$\frac{3}{4}$	$\frac{5}{16}$	$\frac{9}{32}$	$\frac{1}{8}$	$\frac{1}{4}$ DIA.	$\frac{1}{4}$-20UNC-2	$1\frac{1}{2}$
3	$\frac{1}{2}$	$3\frac{7}{8}$	$2\frac{5}{8}$	$\frac{7}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{16}$	$\frac{5}{16}$ DIA.	$\frac{5}{16}$-18UNC-2	2
4	$\frac{5}{8}$	$4\frac{3}{4}$	$3\frac{1}{4}$	1	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{3}{16}$	$\frac{3}{8}$ DIA.	$\frac{3}{8}$-16UNC-2	$2\frac{1}{2}$
5	$\frac{3}{4}$	$6\frac{1}{8}$	$4\frac{3}{8}$	$1\frac{1}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{1}{4}$	$\frac{1}{2}$ DIA.	$\frac{1}{2}$-13UNC-2	$3\frac{1}{2}$

MATERIAL: C R S
CASE HARDEN

DRAWN BY: V.C.L.

PARALLEL CLAMP ADJUSTING SCREW

DWG. NO. 61


$\frac{5}{8}$-11 UNC 2
$1\frac{1}{4}$
$\frac{11}{16}$
$\frac{5}{8}$
$\frac{3}{4}$
$1\frac{1}{2}$
$\frac{9}{32}$
$\frac{15}{32}$
$\frac{3}{4}$

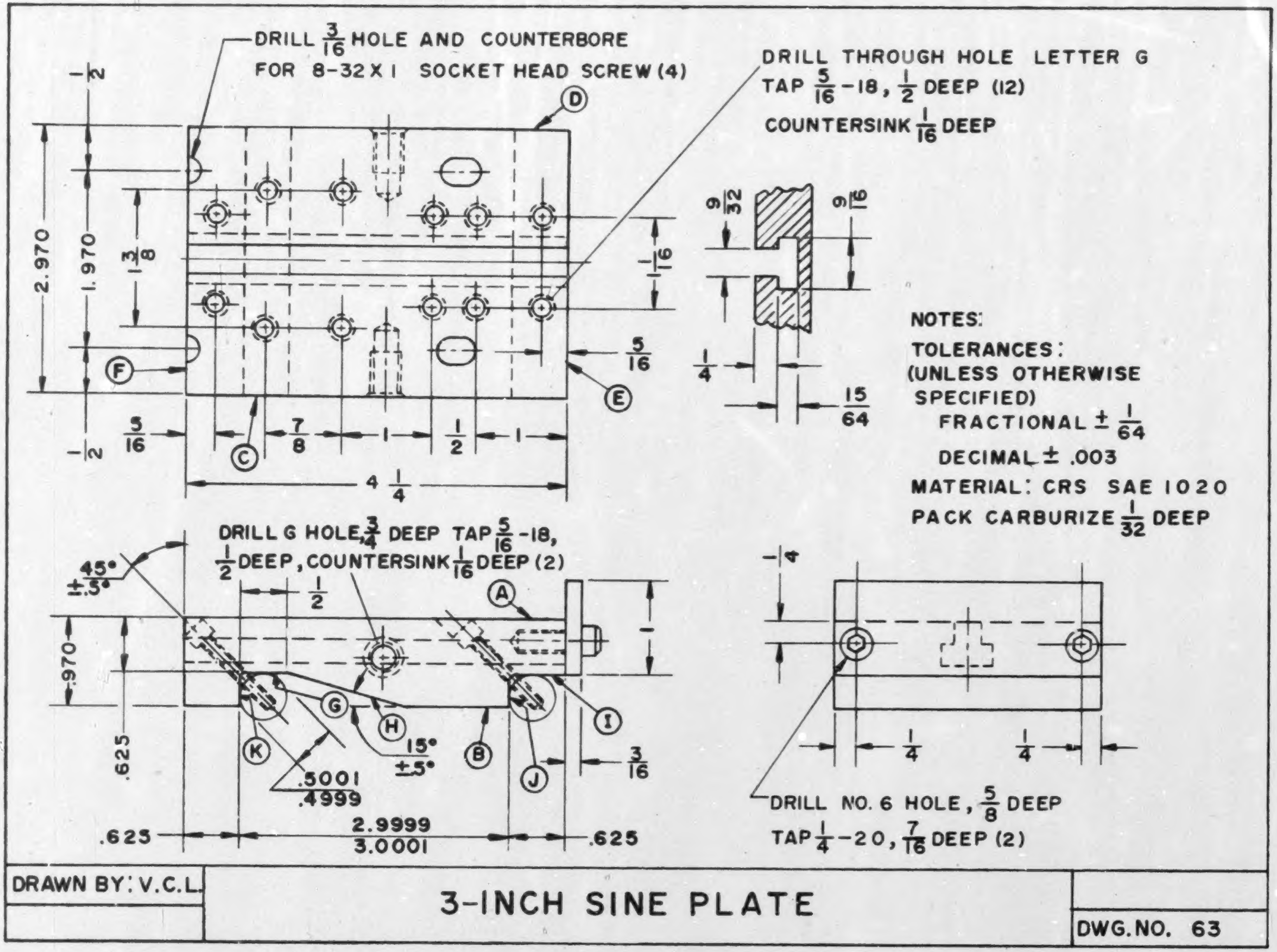
MATERIAL: CRS

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
FRACTIONAL ± $\frac{1}{64}$

DRAWN BY: V.C.L.

T – NUT

DWG. NO. 62


DRILL $\frac{3}{16}$ HOLE AND COUNTERBORE FOR 8-32 X 1 SOCKET HEAD SCREW (4)
DRILL THROUGH HOLE LETTER G TAP $\frac{5}{16}$-18, $\frac{1}{2}$ DEEP (12) COUNTERSINK $\frac{1}{16}$ DEEP
D
E
F
C
$\frac{1}{2}$
2.970
1.970
$1\frac{3}{8}$
$1\frac{1}{16}$
$\frac{5}{16}$
$\frac{7}{8}$
1
$4\frac{1}{4}$
$\frac{9}{32}$
$\frac{9}{16}$
$\frac{1}{4}$
$\frac{15}{64}$
DRILL G HOLE, $\frac{3}{4}$ DEEP TAP $\frac{5}{16}$-18, $\frac{1}{2}$ DEEP, COUNTERSINK $\frac{1}{16}$ DEEP (2)
45° ±.5°
A
B
G
H
I
J
K
15° ±.5°
.5001 .4999
.970
.625
2.9999 3.0001
$\frac{3}{16}$
DRILL NO. 6 HOLE, $\frac{5}{8}$ DEEP TAP $\frac{1}{4}$-20, $\frac{7}{16}$ DEEP (2)

NOTES:

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
FRACTIONAL ± $\frac{1}{64}$
DECIMAL ± .003

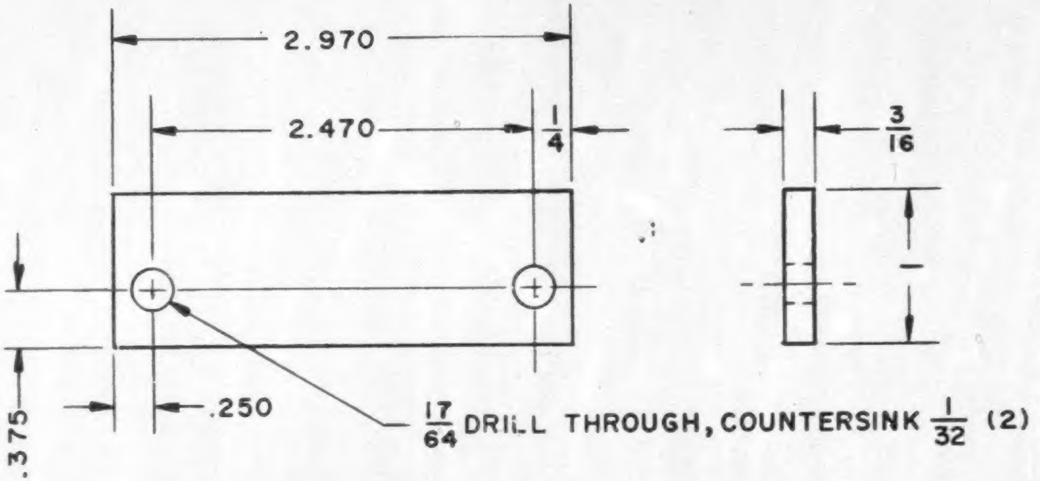
MATERIAL: CRS SAE 1020

PACK CARBURIZE $\frac{1}{32}$ DEEP

DRAWN BY: V.C.L.

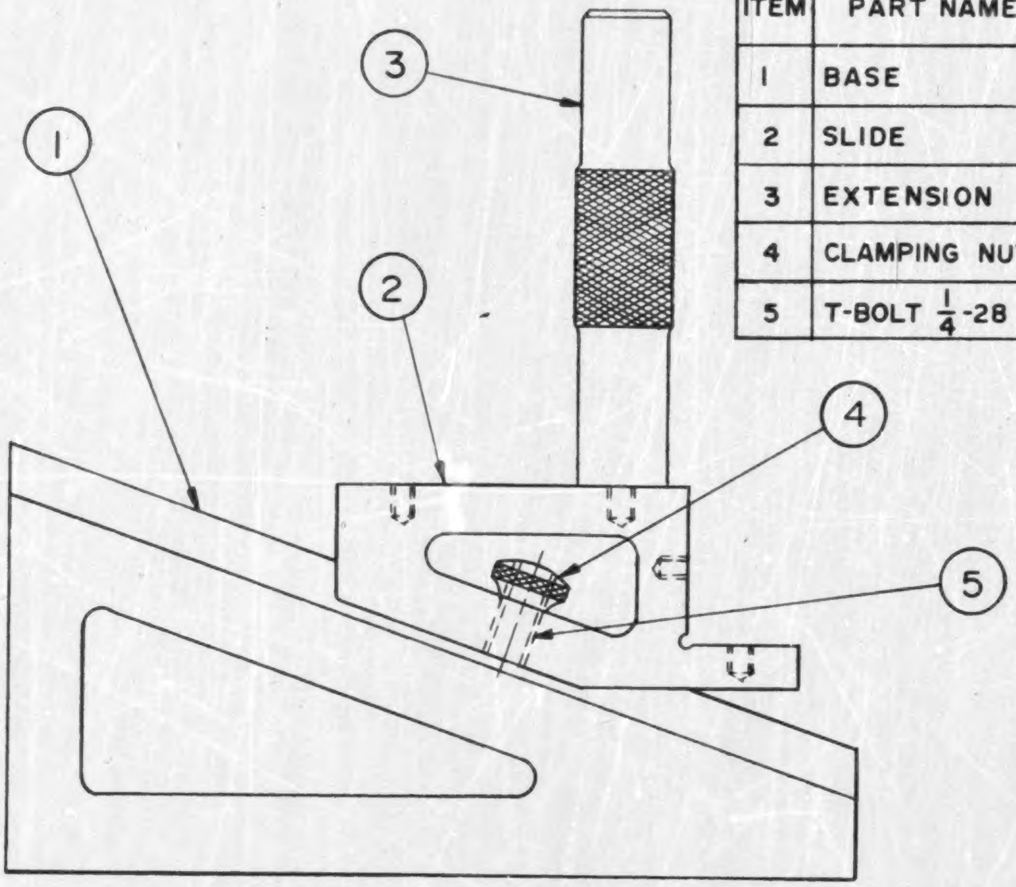
3-INCH SINE PLATE

DWG. NO. 63


2.970
2.470
$\frac{1}{4}$
$\frac{3}{16}$
1
.375
.250
$\frac{17}{64}$ DRILL THROUGH, COUNTERSINK $\frac{1}{32}$ (2)

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
FRACTIONAL ± $\frac{1}{64}$
DECIMAL ± .003

DRAWN BY: V.C.L.	3-INCH SINE PLATE END STOP	DWG. NO. 64

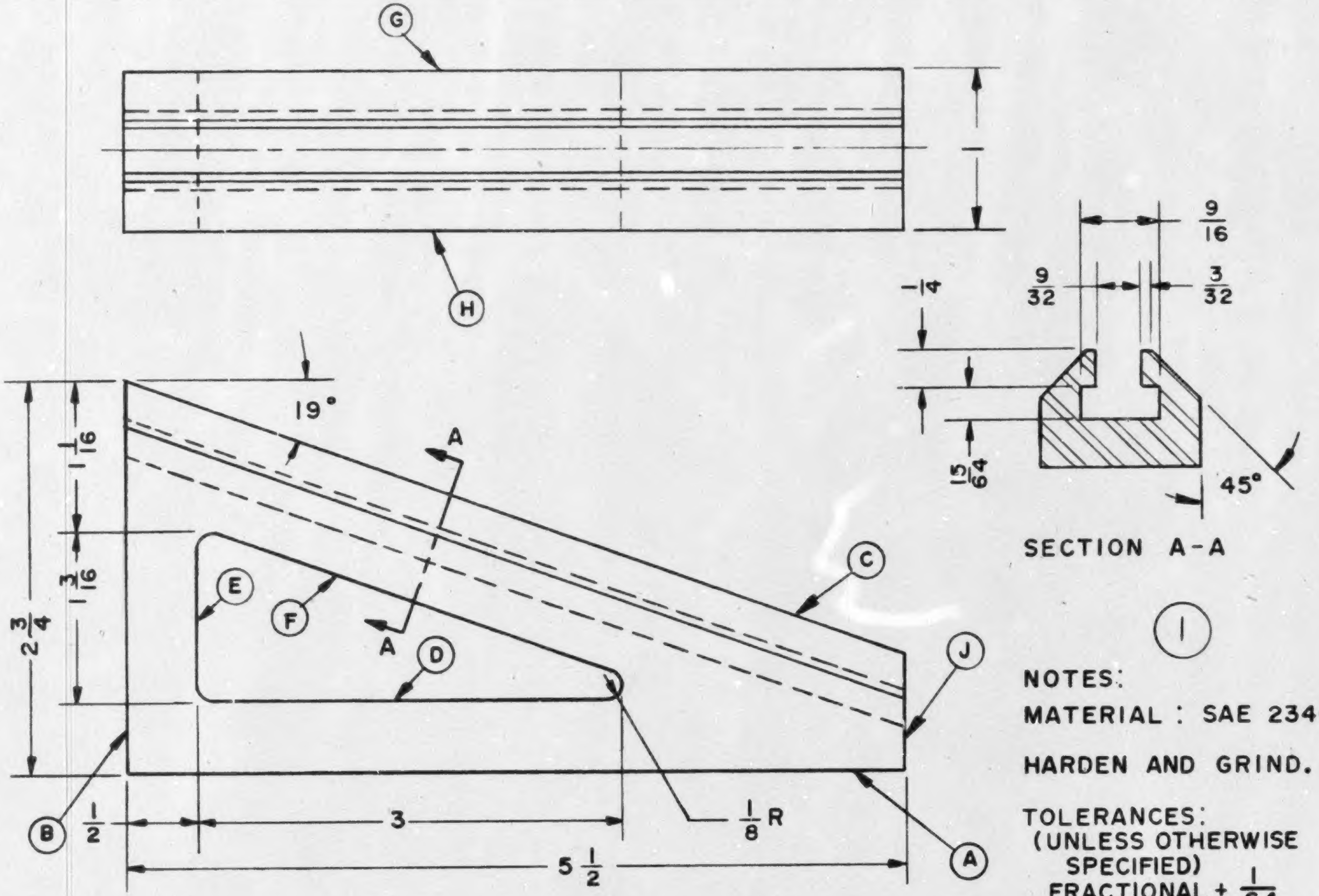


ITEM	PART NAME	MATL.
1	BASE	SAE 2340
2	SLIDE	SAE 2340
3	EXTENSION	SAE 1090
4	CLAMPING NUT	LEDLOY AX
5	T-BOLT $\frac{1}{4}$-28	COMM.

DRAWN BY: V.C.L.

PLANER GAGE ASSEMBLY

DWG. NO. 65


G
H
19°
A
A
C
D
E
F
J
A
B
$2\frac{3}{4}$
$1\frac{1}{16}$
$1\frac{3}{16}$
$\frac{1}{2}$
3
$5\frac{1}{2}$
$\frac{1}{8}$ R
1
$\frac{9}{16}$
$\frac{9}{32}$
$\frac{3}{32}$
$\frac{1}{4}$
$\frac{15}{64}$
45°

SECTION A-A

①

NOTES:

MATERIAL : SAE 2340

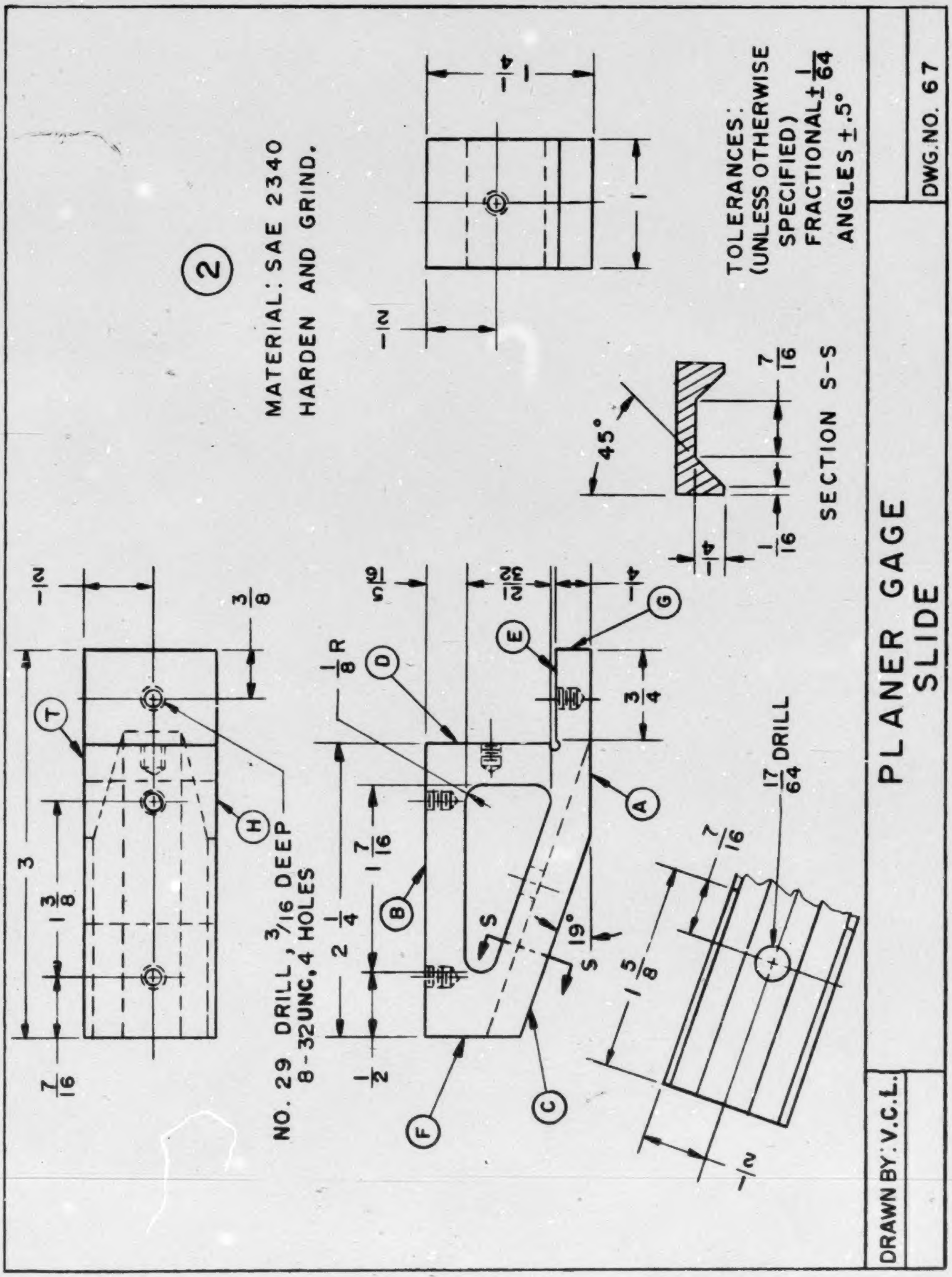
HARDEN AND GRIND.

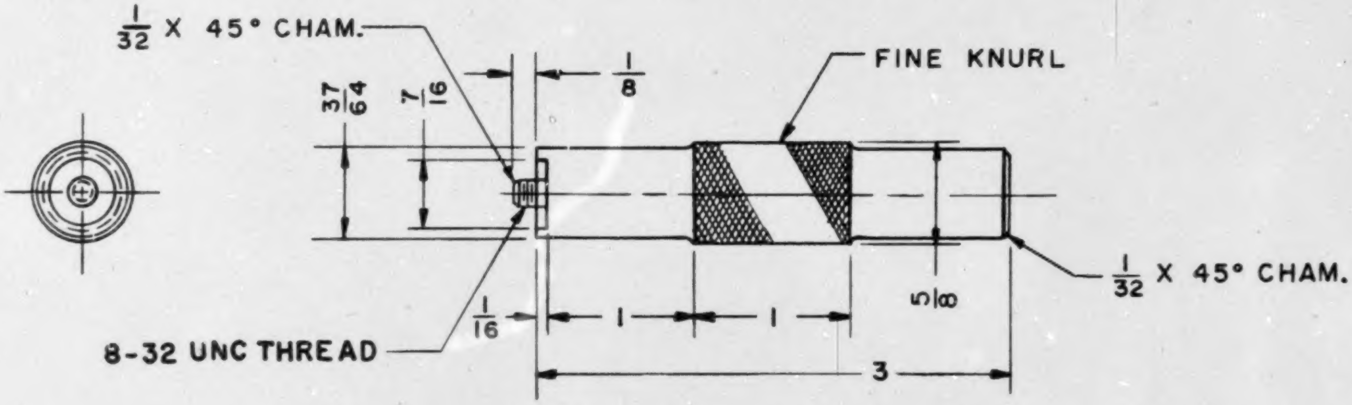
TOLERANCES:
(UNLESS OTHERWISE
SPECIFIED)
FRACTIONAL ± $\frac{1}{64}$
ANGLES ±.5°

DRAWN BY: V.C.L.

PLANER GAGE
BASE

DWG. NO. 66


PLANER GAGE
SLIDE
DRAWN BY: V.C.L.
DWG. NO. 67
②
MATERIAL: SAE 2340
HARDEN AND GRIND.
TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
FRACTIONAL ± 1/64
ANGLES ± .5°
NO. 29 DRILL, 3/16 DEEP
8-32UNC, 4 HOLES
SECTION S-S
17/64 DRILL
1/8 R
45°
19°
3
1 3/8
7/16
3/8
1/2
2 1/4
1 7/16
3/4
1/4
5/16
3/32
1/16
7/16
1 5/8
1
A
B
C
D
E
F
G
H
T
S


1/32 X 45° CHAM.
37/64
7/16
1/8
FINE KNURL
1/16
1
1
5/8
1/32 X 45° CHAM.
8-32 UNC THREAD
3

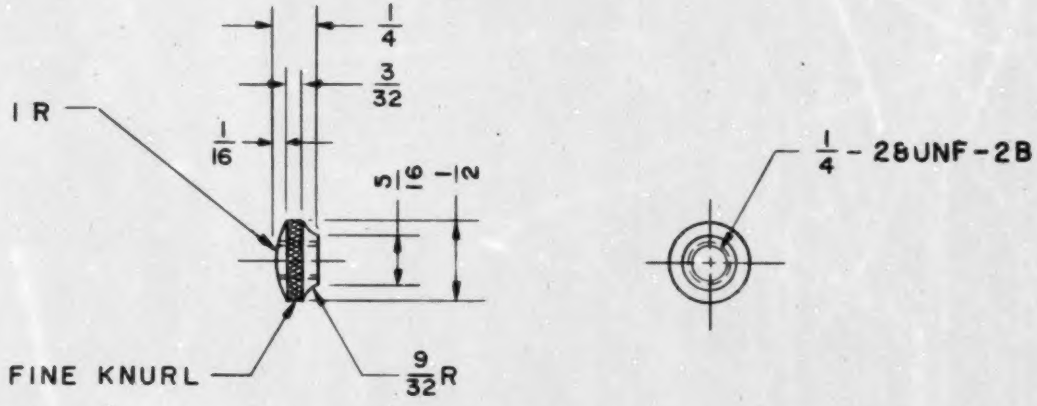
③

MATERIAL: SAE 1090

HARDEN AND GRIND.

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
FRACTIONAL ± 1/64
ANGLES ± .5°

DRAWN BY: V.C.L.	PLANER GAGE EXTENSION	DWG. NO. 68

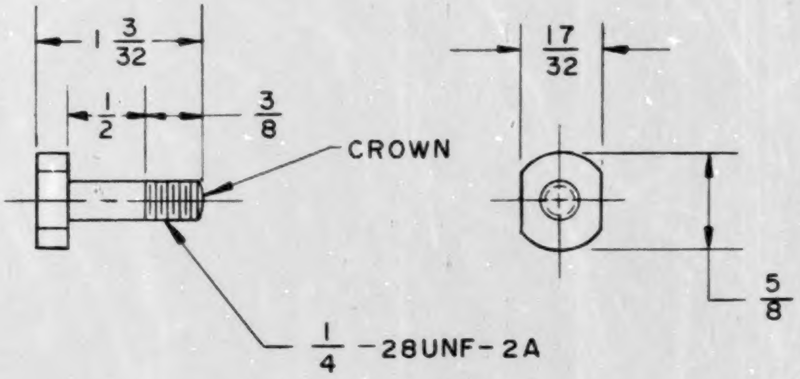

$\frac{1}{4}$
$\frac{3}{32}$
I R
$\frac{1}{16}$
$\frac{5}{16}$
$\frac{1}{2}$
FINE KNURL
$\frac{9}{32}$R
$\frac{1}{4}$ - 28UNF-2B

④

MATERIAL: LEDLOY AX

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
FRACTIONAL $\pm\frac{1}{64}$

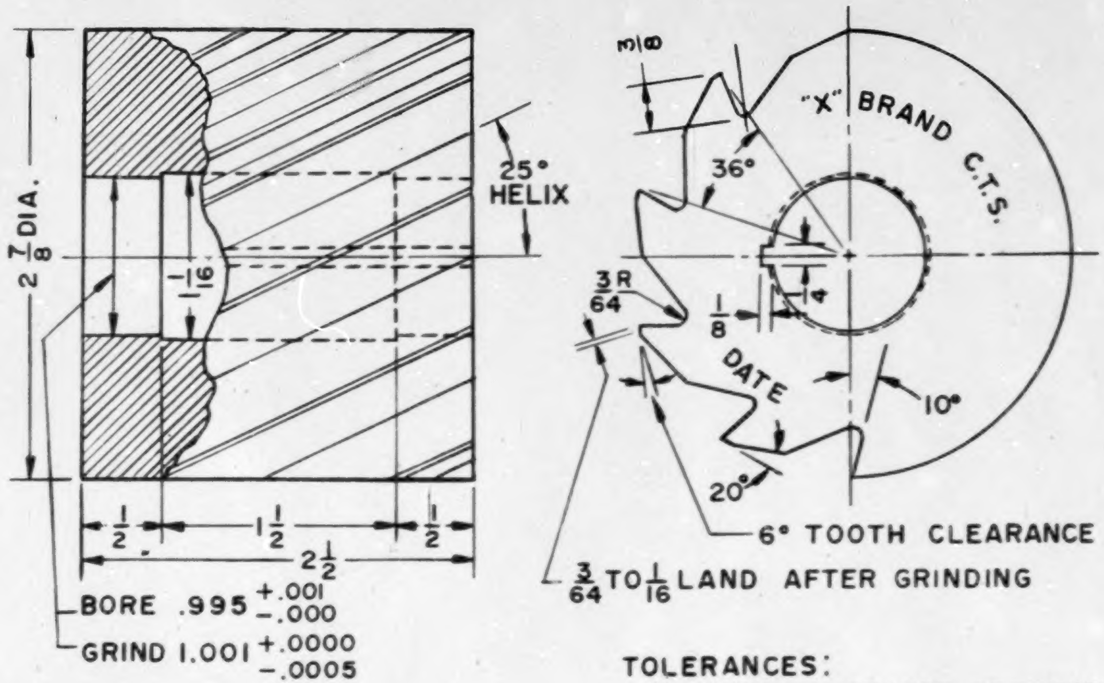
DRAWN BY: V.C.L	PLANER GAGE CLAMPING NUT	DWG. NO. 69


$1\frac{3}{32}$
$\frac{1}{2}$
$\frac{3}{8}$
CROWN
$\frac{1}{4}$ -28UNF-2A
$\frac{17}{32}$
$\frac{5}{8}$

MATERIAL: SAE 1018

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
FRACTIONAL ± $\frac{1}{64}$

DRAWN BY: V.C.L.	PLANER GAGE T-BOLT	
		DWG.NO. 70


2 7/8 DIA.
1 1/16
25° HELIX
1/2
1 1/2
1/2
2 1/2
BORE .995 +.001 −.000
GRIND 1.001 +.0000 −.0005
3/8
36°
"X" BRAND C.T.S.
3R/64
1/8
1/4
DATE
10°
20°
6° TOOTH CLEARANCE
3/64 TO 1/16 LAND AFTER GRINDING

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
FRACTIONAL ± 1/64, ANGLES ± .5°

10° RAKE TOOTH HELICAL MILLING CUTTER

MATERIAL: HIGH-SPEED STEEL

DRAWN BY: V.C.L

HELICAL MILLING CUTTER

DWG. NO. 71